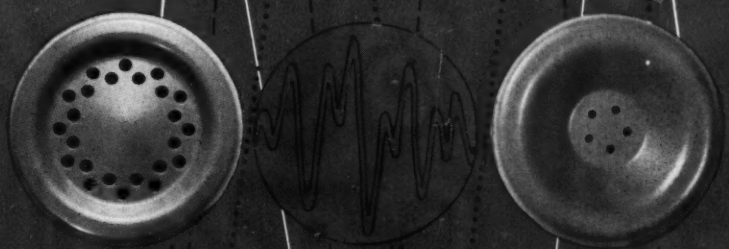
THE UNIVERSITY OF MICHIGAN
MAY 25 1960
ENGINEERING LIBRARY

APRIL 1960
VOLUME 7 NO. 2

AUTOMATIC ELECTRIC TECHNICAL JOURNAL



GENERAL SYSTEM

APRIL, 1960 VOL. 7, NO. 2

The Automatic Electric Technical Journal is published by Automatic Electric Laboratories, Incorporated, a subsidiary of Automatic Electric Company, Northlake, Illinois.

For additional copies, please address the Editor.

AUTOMATIC ELECTRIC TECHNICAL JOURNAL

CONTENTS

NEW TYPE 180 TOLL TEST BOARD ..... Page 40

By combining primary, secondary, and Wheatstone Bridge tests in a single panel, with an associated lower unit providing the keyshelf and other mounting facilities, a more compact test board is provided for smaller toll centers, and greater efficiency is achieved in larger installations.

NUEVA MESA DE PRUEBA DE LARGA DISTANCIA TIPO 180

Un solo panel que combina pruebas primarias, secundarias y de puente Wheatstone, está asociado con su unidad inferior que contiene el pupitre de llaves y las demás facilidades de montaje, y logra una mesa de pruebas compacta para centros de larga distancia pequeños con mayor eficiencia en instalaciones grandes.

NEW TRANSISTORIZED AMPLIFIER ..... Page 48

For use on toll service observing desks, this new amplifier is designed as a "plug-in" unit—easily removed for maintenance purposes. It can be connected across toll lines without appreciably reducing transmission volume, provides better gain, and reduces current drain.

NUEVO AMPLIFICADOR TRANSISTORIZADO

Para usarse en las mesas de observación de servicio de larga distancia; diseñado como una unidad "enchufable"—fácilmente removible para fines de mantenimiento. Puede conectarse a las líneas de larga distancia sin reducir apreciablemente el nivel de transmisión, proporciona mejor ganancia y reduce el drenaje de corriente.

A 100-LINE ELECTRONIC PRIVATE AUTOMATIC TELEPHONE SWITCHBOARD Page 50

This experimental electronic switchboard provides voice-frequency connections through the use of PNPN silicon diodes in a four-stage network. A ferrite-core memory is used, and control action is performed by common equipment which is time-shared by all subscribers.

CENTRALITA ELECTRONICA DE 100 LINEAS

Esta centralita electrónica experimental ofrece conexiones a frecuencia de voz mediante el uso de diodos PNPN de silicón en una red de cuatro etapas. Se emplea una "memoria" de núcleo de ferrita y la acción de control es efectuada por el equipo común compartido a base de tiempo por todos los abonados.

EDITORIAL STAFF

WALTER AXELSEN,
Editor

LAURENCE O. SMITH,
Associate Editor

EDITORIAL ADVISORY BOARD

F. D. REESE
D. E. CLARK
C. W. FRANK
C. F. FFOLLIOTT
F. L. KAHN
J. N. PETRIE
I. MOLNAR

R. STEHLIK
P. HANOTTE
Antwerp, Belgium

A. MANNUCCI
C. MIGLIASSO
Milan, Italy

W. W. ASHWORTH
C. R. HUGHES
Brockville, Canada

Copyright 1960 by
Automatic Electric Laboratories, Inc.

CONTENTS (Continued)

NEW NEGATIVE-IMPEDANCE REPEATER PERMITS ACCURATE IMPEDANCE MATCHING . . . . . **Page 59**

A new, fully transistorized unit, combining series and shunt repeater facilities, with very simple means for making adjustments for application to a specific circuit. Design makes it possible to secure the highest practicable return loss without "singing", thus eliminating "talker echo".

NUEVO REPETIDOR DE IMPEDANCIA NEGATIVA PERMITE EXACTO EQUILIBRIO DE IMPEDANCIAS

Una unidad nueva completamente transistorizada, combina facilidades de repetidores en serie y en paralelo simplificados para ajustarse a un circuito específico. Su diseño hace posible obtener la más alta pérdida de retorno practicable sin "canto", eliminando así el "eco".

PORTABLE TELEPHONE EXCHANGE PROVIDES SERVICE TO NEW COMMUNITIES . . . . . **Page 68**

Alberta (Canada) Government Telephones quickly provides temporary telephone service to subscribers by using a portable building which can be moved on a low-bed trailer. With the addition of a portable, engine-driven, a.c. power supply, the portable exchange also provides emergency service in case of disasters which interrupt regular telephone service.

CENTRAL TELEFONICA PORTATIL PROVEE SERVICIO A COMUNIDADES NUEVAS

Alberta (Canada) Government Telephones provee rápidamente servicio telefónico temporal a sus abonados usando una caseta móvil montada en un remolque de plataforma baja. Mediante un equipo portátil de fuente de alimentación de c.a., impulsado por un motor de combustión interna, esta central proporciona también servicio de emergencia en casos de desastres que interrumpen el servicio telefónico.

THE CLASS "W" WIRE-SPRING RELAY . . . . . **Page 76**

A new, long-life, high-reliability industrial relay that will switch 51 sets of contacts at one time, with very low operating power. Twin contacts, mounted on wire springs, are self-equalizing, and capable of transferring 3 amperes at 50 volts (non-inductive load); maximum contact resistance is 0.100 ohm. Relay can be supplied with 17, 34, or 51 sets of contacts.

RELEVADOR CON RESORTE DE ALAMBRE CLASE "W"

Un relevador industrial nuevo, durable, de alta confiabilidad, que conmuta 51 juegos de contactos a la vez con muy baja fuerza de operación. Los contactos gemelos, montados en resortes de alambre, se autoigualan y son capaces de transferir 3 amperes a 50 voltios (carga no inductiva); la resistencia máxima de contacto es de 0.100 ohmios. Puede suministrarse con 17, 34 o 51 juegos de contactos.

THE TYPE 59 "CODEL" RELAY . . . . . **Page 84**

One four-coil relay replaces the cluster of four separate relays otherwise used in the Strowger Automatic Toll Ticketing System, for storing digital information in "Codel" form. The new relay has fewer parts, is permanently adjusted in the factory, and provides twin contacts for maximum reliability.

RELEVADOR "CODEL" TIPO 59

Este relevador de 4 bobinas reemplaza el grupo de cuatro relevadores individuales que se usaban en el Sistema Automático Strowger de Boletas de Larga Distancia, para registrar información digital en forma "Codel". Este nuevo relevador tiene menos piezas, es ajustado permanentemente en la fábrica y provee contactos gemelos para máxima confiabilidad.

Type 180 Toll Test Board Installation at
Inter-County Telephone Co.,
Avon Park, Florida

◀

THE TYPE 180 TOLL TEST BOARD

By: J. P. Jallits

The substantial increase in toll circuits, even in smaller toll centers, and the popularity of operator toll dialing, with corresponding reduction in ring-down circuits, have changed toll-testing practices and created a demand for a more flexible, compact, and modern toll test board. The new Type 180 Toll Test Board (illustrated) has been created to meet these requirements. It can be engineered to provide the desired primary jacks, secondary jack circuits, and patching jacks required for any combination of toll trunk circuits.

Used with Automatic Electric Types 20, 30, 31B and 31C toll switchboards, this new test board permits both primary and secondary testing of toll circuits, using either a separate position for each, or a combination position. (Primary tests are tests of outside plant facilities on toll or telegraph lines. Secondary tests are overall tests, such as monitoring, signaling, talking, and transmission measurements.) The secondary testing circuit provides standard overall testing features for intertoll dialing (as well as for ring-down) trunks terminating in these boards—all having the signaling equipment located on the line side of the patching jacks.

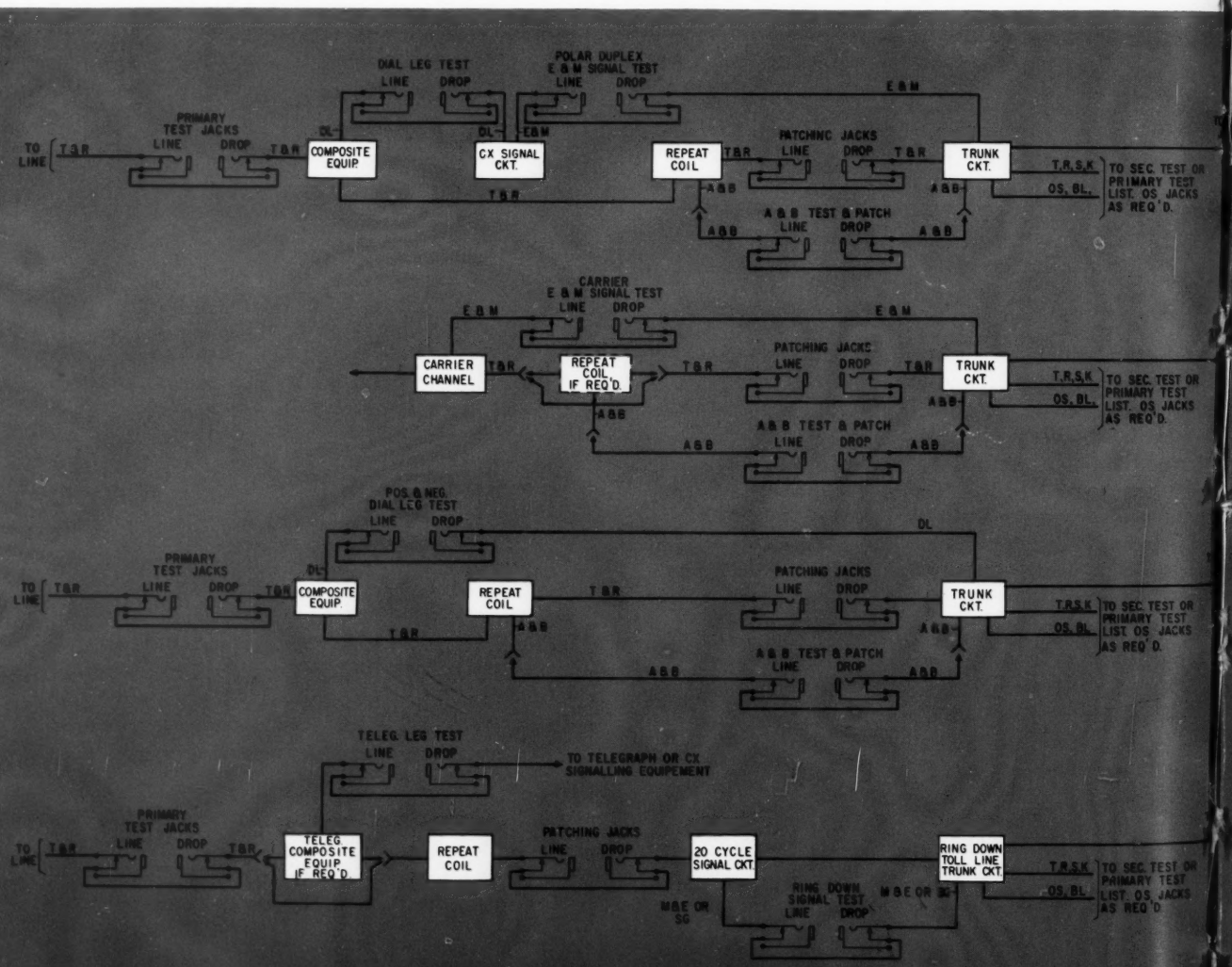
The provision of secondary testing facilities is highly desirable as it enables the test-board attendant to extend calls by dialing or keysending, exactly as if the call had originated on the toll board. The secondary tests are more important with toll dialing than they were with ring-down operation; thus, the combination of primary and secondary test functions on the same positions is now considered the normal arrangement.

The new test board is not designed to work with older toll boards nor with toll boards of other makes. However, it is possible to provide, for primary testing only, a lower unit consisting of a Wheatstone bridge, a volt-milliameter and an operator's telephone circuit; thus equipped, the Type 180 test panel can be used with other types of toll boards than mentioned above.

Each test panel consists of a jack field and a "lower unit" which provides mounting facilities for the test equipment, together with a keyshelf with keys and plugs for connection to the trunk under test. This equipment mounts on a 24⅜" relay-rack framework, as shown in the illustration.

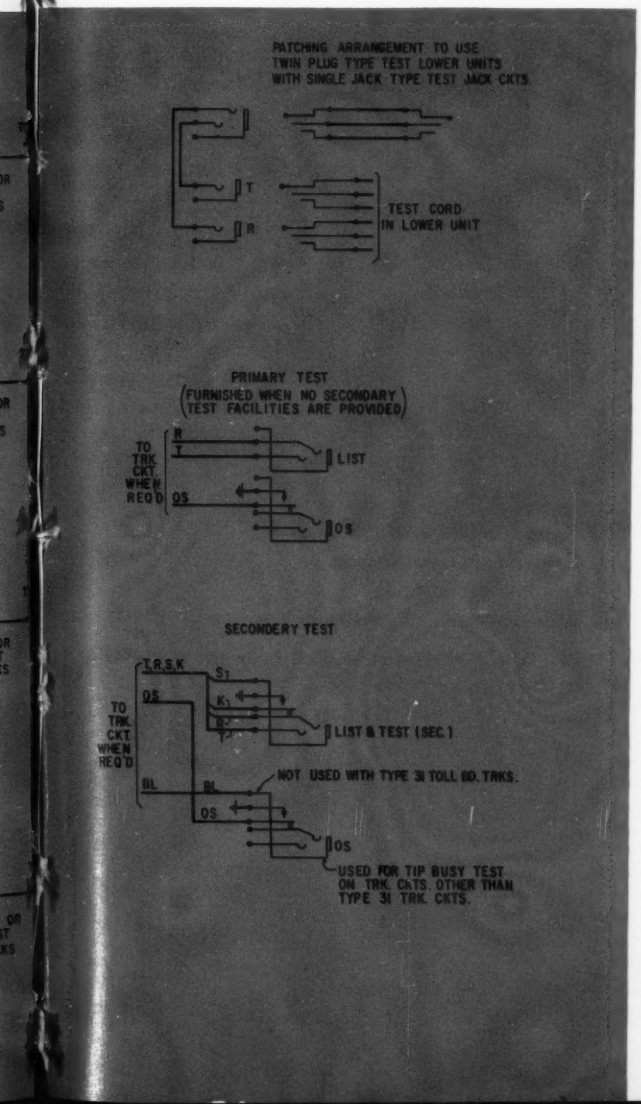
The Type 180 Toll Test Board (Continued)

Figure 1. Typical Single-Jack Arrangement for Polar Duplex, Carrier, Positive-Negative and Ringdown Trunks



JACK-FIELD EQUIPMENT

The capacity of the jack field has been practically doubled by utilizing a single jack for the tip and ring conductors instead of the former, more conventional, twin jacks; it is also made as flexible as possible, to meet various job requirements. The field is furnished without terminal blocks at the top of the unit; the installer will cable directly to the jack field from the distributing frame, thus making this equipment applicable with any combination of jack circuits. Figure 1 shows a typical jack layout for Polar Duplex, Carrier, Positive-Negative, and Ring-down-type trunks. These jack facilities will be briefly described; readers familiar with toll testing will recognize the circuits as conventional (except for the elimination of separate tip and ring conductors).



Test Jacks

Each toll trunk is associated with primary test jacks on the line side of the office equipment to provide a means for patching and testing either open-wire or cable toll lines. When required, telegraph-leg jacks can be furnished. A meter or test set may be placed in series with a telegraph circuit to measure current or voltage, or for monitoring. Similarly, dial-leg jacks in the dial toll trunks —between the composite signaling equipment and the composite set—permit a meter or test set to be placed in series with the line, to show the current or voltage in the signaling leg of the dial trunk.

A set of E and M signaling jacks permit access to a point between the composite signaling equipment and the trunk relay equipment. A signaling test set (provided optionally) can be mounted above the jack field and inserted into the E and M signaling jacks to measure the percent-make of dial pulses received from either the toll line or the office. The test set also has facilities to monitor and transmit supervisory signals to either the line or the drop equipment.

Patching jacks are provided to obtain access to a point between the trunk relay equipment and the repeat coil equipment. By means of these jacks the drop equipment circuits may be associated with the transmission path of any dial toll trunk. Patching jacks are also furnished for ringdown toll trunks, to obtain jack access to a point between the signaling equipment and the trunk relay equipment. They provide means by which the drop equipment can be associated with any ringdown toll trunk, regardless of the type of signaling employed on it.

Each toll trunk appearing at the switchboard will have one listen-test and one out-of-service (OS) jack located at the toll test board. The listen-test jack provides an access to toll circuits at a point equivalent to the swichboard or selector bank multiple; this permits the toll test man to determine if a toll circuit is busy, and also to check the overall performance (dialing, supervision, ringing, and transmission losses) of these trunks. A tip-busy test circuit is used to indicate busy trunk circuits.

The out-of-service (OS) jack accommodates a "dummy" plug, to remove the trunk from service when desired.

Other Equipment Mounted in or Above Jack Field

Separate jack-ended circuits are used for trunks between the test board and the switchboard and other operating room facilities. Twenty-cycle ringdown and holding features are provided as a separate jack-ended applique circuit, thus avoiding tying up any of the primary cords, as was the practice on former test boards.

Other units mounted above the jack field as required are: a 4-cycle interrupter used for open-location and capacity tests, with the Wheatstone bridge; a signaling test set; two way trunks to local switching equipment, incoming trunks from intertoll selectors and transmission test facilities.

LOWER UNIT

The lower unit includes a keyshelf and other mounting facilities for the various primary and secondary toll test equipment, and the plugs and keys necessary to associate this unit with the trunk under test. The unit mounts on the face of the 24⅜″ rack, with the keyshelf 37⅜″ from the floor. The plugs are mounted on a sloping plug-shelf, and the relay equipment on mounting plates directly below the keyshelf. A front panel and foot-rail are provided to protect the relay equipment.

The keyshelf (see Figure 2) is 15⅞″ deep, and is divided into two sections. The left-hand section is used for mounting the keys of the secondary test cords, a dial or keyset, the primary test keys, and the volt-milliameter. The right-hand section is used to mount the Wheatstone bridge; when a bridge is not provided, a Plexiglas covering is placed over this section, as a bulletin holder.

The plug-shelf rises at a 30-degree angle from the keyshelf. Three single-plug cords (tip and ring), one single-plug cord (tip and sleeve), and one single-plug cord (tip) are provided for primary testing. For secondary testing, two cord pairs with single plugs (front and rear) may be provided for toll trunks terminating directly on the toll-board multiple, and two cord pairs with one twin and one single plug (front and rear) for toll circuits normally accessed via the selector multiple only.

Primary Test Circuit

The primary test facilities permit testing and analyzing line troubles by means of a volt-milliameter; finding the location of line faults with a Wheatstone bridge; and talking, monitoring, and ringing on toll lines. The test circuit includes 20-cycle ringing, and furnishes talking battery to a repairman.

The meter, used as either a voltmeter or a milliameter by the operation of the proper keys, is located at the front of the keyshelf. The primary test circuit terminates in the two single plugs A and B, one single plug TG, and two single plugs C. The A, B, and TG plugs may be connected through keys to the meter, or to the operator's telephone circuit. With these plugs the following tests may be made:

1. Busy test, using voltmeter
2. Continuity tests
3. Tests for shorts or grounds
4. Bridge capacitance tests
5. Insulation resistance
6. Measurements of telegraph currents

The two single plugs C are used only with the meter or Wheatstone bridge.

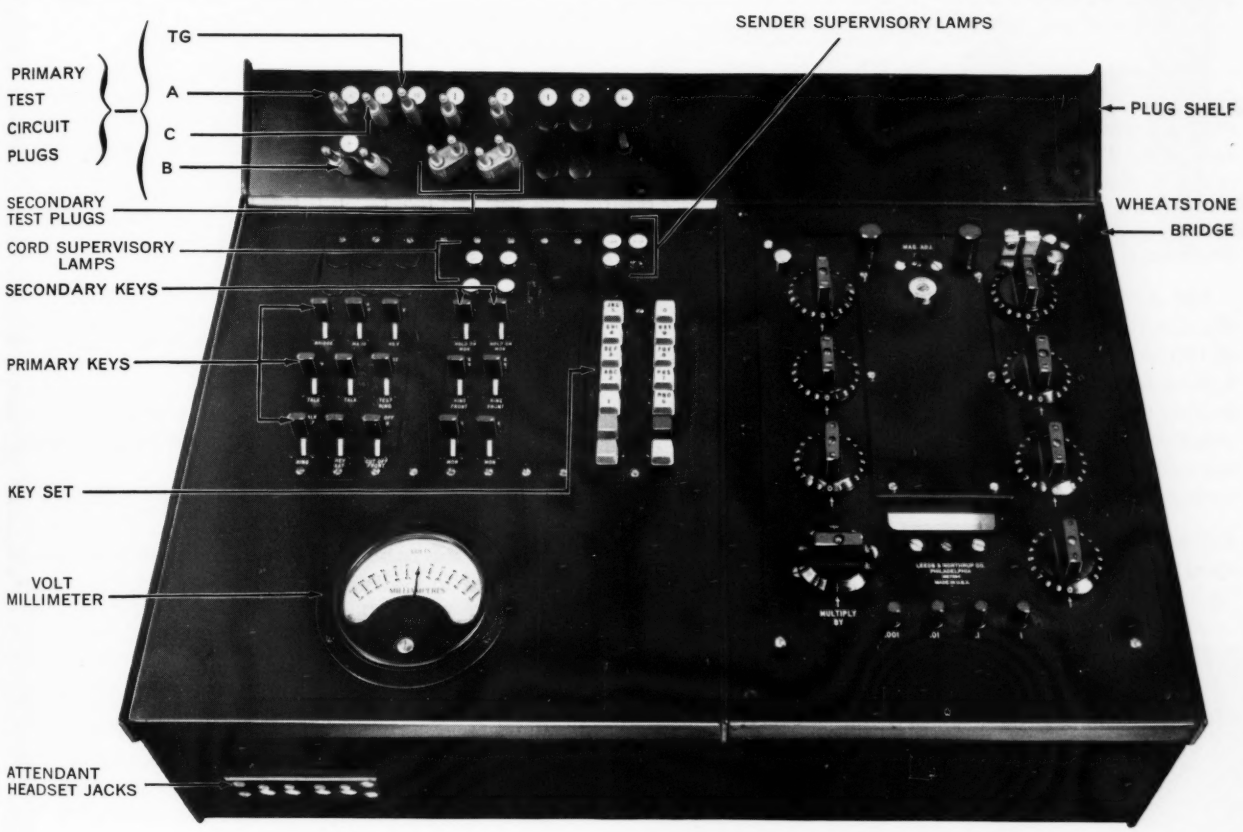


Figure 2. Lower Unit, with Wheatstone Bridge

Wheatstone Bridge Circuit

The Wheatstone bridge is intended for locating faults on cable or open-wire conductors by picking up the circuits directly at the primary jacks. With the exception of the Murray Loop, which is now rarely used, all the Wheatstone bridge tests which have heretofore been provided at toll testboards are retained, but the methods have been somewhat modified, due to certain circuit simplifications.

Jack terminations, keys for the Wheatstone bridge, and the potentiometer for the suppression of induced potentials, are mounted in the upper unit on a miscellaneous key strip. The 4-cycle interrupter associated with the bridge is also in the upper unit, above the jack field.

Secondary Test Circuit

The secondary test circuit is essentially the same as the circuits of the A.E. Type 31 toll board; it consists of two to four pairs of cords for secondary testing, and a common position circuit for splitting the cords or connecting them to the test operator's telephone circuit. The operator's telephone circuit is common to both the primary and secondary cords, and is equipped with a transistorized monitor amplifier (described on page 48).

The secondary test cords serve as patching and holding cords, and together with the position circuit, provide a means of talking, ringing, and dialing or key-pulsing on trunks, as required. They are used to:

Access individual toll circuits terminated on toll-board jacks or intertoll selector banks, for testing and talking.

Routine intertoll trunks with reference to dialing, supervision, ringing, and transmission loss.

Ascertain the nature of trouble on intertoll trunks, in order that immediate corrective action may be taken.

SUMMARY

The new Type 180 Toll Test Board affords greater flexibility than earlier designs, and increased capacity in the jack field arrangements. Instead of requiring separate panels for primary, secondary, and Wheatstone bridge tests, these three functions can now be combined in a single panel and associated lower unit; thus a smaller test board is adequate for small toll centers, while greater efficiency of operation is achieved on larger installations. The testing circuits and method of operation have been simplified, and this should result in overall economy and increased reliability of operation.

JOSEPH P. JALLITS graduated from Illinois Institute of Technology in 1950, with the degree of B.S. in Electrical Engineering. He joined Automatic Electric that same year as a student in the training school. Following completion of the course, he was assigned to Installation, Exchange Engineering, and the Testing Bureau. He is now assigned to the Telephone Switching Systems Department of the Laboratories as a project engineer, where he is presently doing development work on test equipment and automatic routiners. He is a member of the American Institute of Electrical Engineers.

New Series of "MONOGRAPHS" Will Supplement Technical Journal

Among the papers offered to the editor of the Technical Journal by members of our Laboratories and Engineering staffs, there are many which would be of great interest and value to a limited number of our readers, but are not of such general interest as to justify publication in the Journal. To make these papers available to our readers, we have recently begun publication of a new series of "Monographs". Certain papers already published in the Journal will also be included in this series, so as to make them available to readers desiring additional copies.

The Monographs presently in preparation are outlined below; as additional papers in this series are prepared they will be made available through the Technical Journal. To receive copies of those in which you are interested, simply address your request to "The Editor, Automatic Electric Technical Journal, Northlake, Ill."

MONOGRAPH NO. 1—Electronic Switching—by R. C. Stiles. A reprint of the article which appeared in our January, 1959, issue.

MONOGRAPH NO. 2—Evolution and Behavior of the "B" Function Relay—by R. B. King. A discussion of this relay (which is basic to the Strowger Automatic system) and of the developments through the years, which have increased its operating range and reliability. Mr. King writes from a background of thirty-five years with Automatic Electric, during all of which time he has been closely associated with relay development and application.

MONOGRAPH NO. 3—A Practical Method for the Prediction of Relay Operate Time—by R. E. Stoffels. A presentation, with several nomographic charts, of a simple method of calculating the operate time of a relay.

MONOGRAPH NO. 4—Emergency Restriction Line and Trunk Load-Control—by J. C. Colbourne and D. C. Zukausky. A description of facilities available for restricting telephone service in time of disaster or emergencies, so as to assure service to certain key subscribers and personnel.

MONOGRAPH NO. 5—Trends in North American Telecommunications—by Dr. I. Molnar. A brief survey of current developments in this area, of interest particularly to telephone engineers and executives outside the United States and Canada.

TALKS AND PAPERS — The following is a list of speakers, titles, papers, and places of presentation for recent talks presented by members of the Automatic Electric Laboratories.

NATIONAL ELECTRONIC INDUSTRIES ASSOCIATION CONFERENCE, October 13, 1959, Chicago, Ill.

- DONALD K. MELVIN, *"The Application of Digital Computer Techniques to Electronic Automatic Telephone Switching Systems"*.
- JOHN G. VAN BOSSE, *"A Fully Electronic Private Automatic Telephone Switchboard"*.

A.I.E.E. NATIONAL SYMPOSIUM, October 14, 1959, Chicago, Ill.

- PETER E. OSBORN, *"Ferrite Core Distributor and Memory System for a Small Electronic Telephone Exchange"*.

ETTA KAPPA NU CHAPTER MEETING, February 17, 1959, University of Wisconsin.

- DONALD K. MELVIN, *"Introduction to Electronic Telephone Switching Systems and Memory Requirements and Techniques"*.
- K. C. HEYDA, *"Digital Encoding Techniques in Communications Systems"*.

JOURNAL OF PHYSICS AND CHEMISTRY OF SOLIDS, January, 1959, Issue.

- DR. THOMAS A. LONGO, *"Low Temperature Impurity Conduction in Silicon"*.

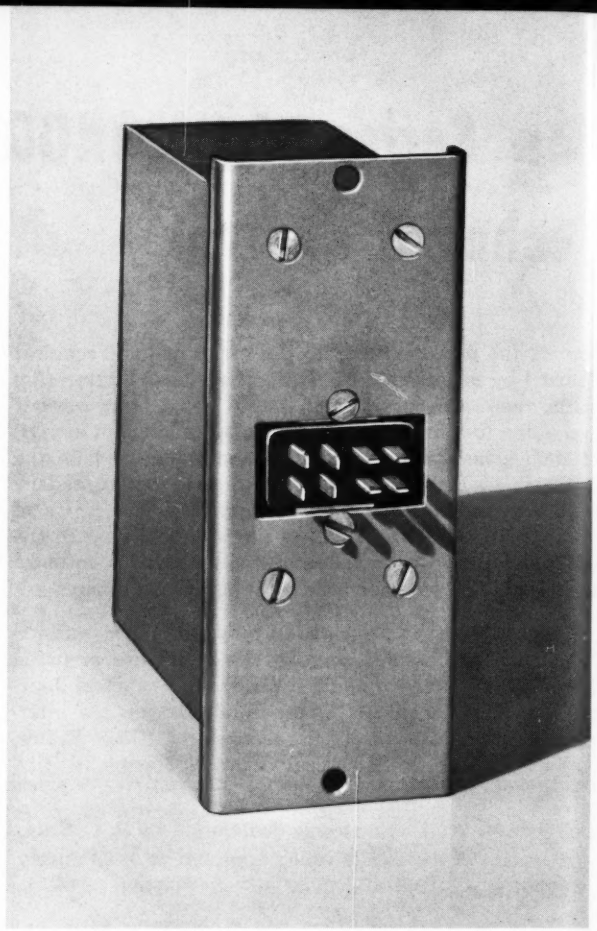


Figure 1. Transistorized Monitoring Amplifier

NEW TRANSISTORIZED AMPLIFIER

. . . for monitoring toll service

Automatic Electric Laboratories has designed a Transistorized Monitoring Amplifier for toll service observing desks, which replaces the former vacuum-tube type. As shown in Figure 1, the new unit is of "plug-in" design—easily removed for maintenance purposes. It can be connected across the toll lines without disturbing repeater balance or appreciably reducing transmission; it provides better gain, and reduces current drain.

OPERATION

The operator, when observing a toll call, inserts a headset plug into the jack of the toll service observing desk, thus closing the exchange battery to the amplifier circuit. By operating a cord key on the desk, leads TM and RM (see Figure 2) are connected across the toll trunk which is to be monitored.

CIRCUIT FEATURES

- Transformer-coupled input impedance of 5000 ohms.
- Transformer-coupled output impedance of 500 ohms.
- Single-stage, capacitive-coupled, transistor amplifier, arranged for volume control.
- Power gain of 27db, and insertion attenuation imperceptible to the position being monitored.
- Operates on 48-volt battery.

CIRCUIT OPERATION

Voice-frequency currents are introduced as the input signal over the two leads TM and RM, through d-c blocking capacitor C4, to the primary winding of input transformer T1. This transformer presents an impedance of 5000 ohms across the toll trunk; since this is relatively high compared to the trunk impedance, no appreciable transmission disturbance occurs on the trunk.

The input signal voltage is induced in the secondary of input transformer T1, and also appears across volume control potentiometer P1 and resistor R1, in parallel. A portion of the input signal is also applied from the center tap of potentiometer P1, through coupling capacitor C1, and across resistor R5. The input signal is amplified by the transistor, the output flowing from the collector through the primary of the output transformer T2. A portion of the output signal is fed back through resistor R2 to the base of the transistor, for stabilization of the amplifier.

Capacitor C3 shunts emitter resistor R6 to prevent degeneration and loss of gain. Capacitor C2 (connected between negative battery and ground) provides a bypass for the voice-frequency component of current.

As the amplified signal current flows through the primary winding of output transformer T2, corresponding voltage is induced in the secondary winding which connects leads R and T to the operator's headset. This secondary winding, having an impedance of 500 ohms, should be connected to the headset with similar impedance, to prevent loss of gain and also frequency discrimination due to impedance mismatch.

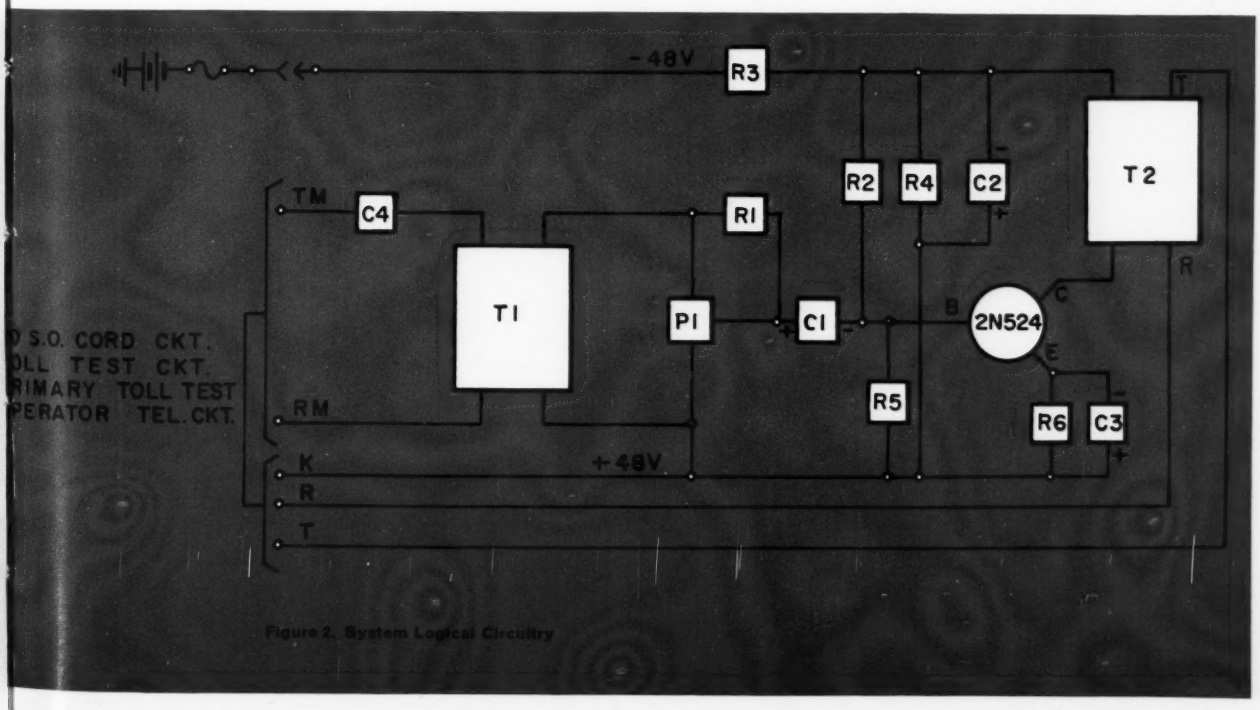
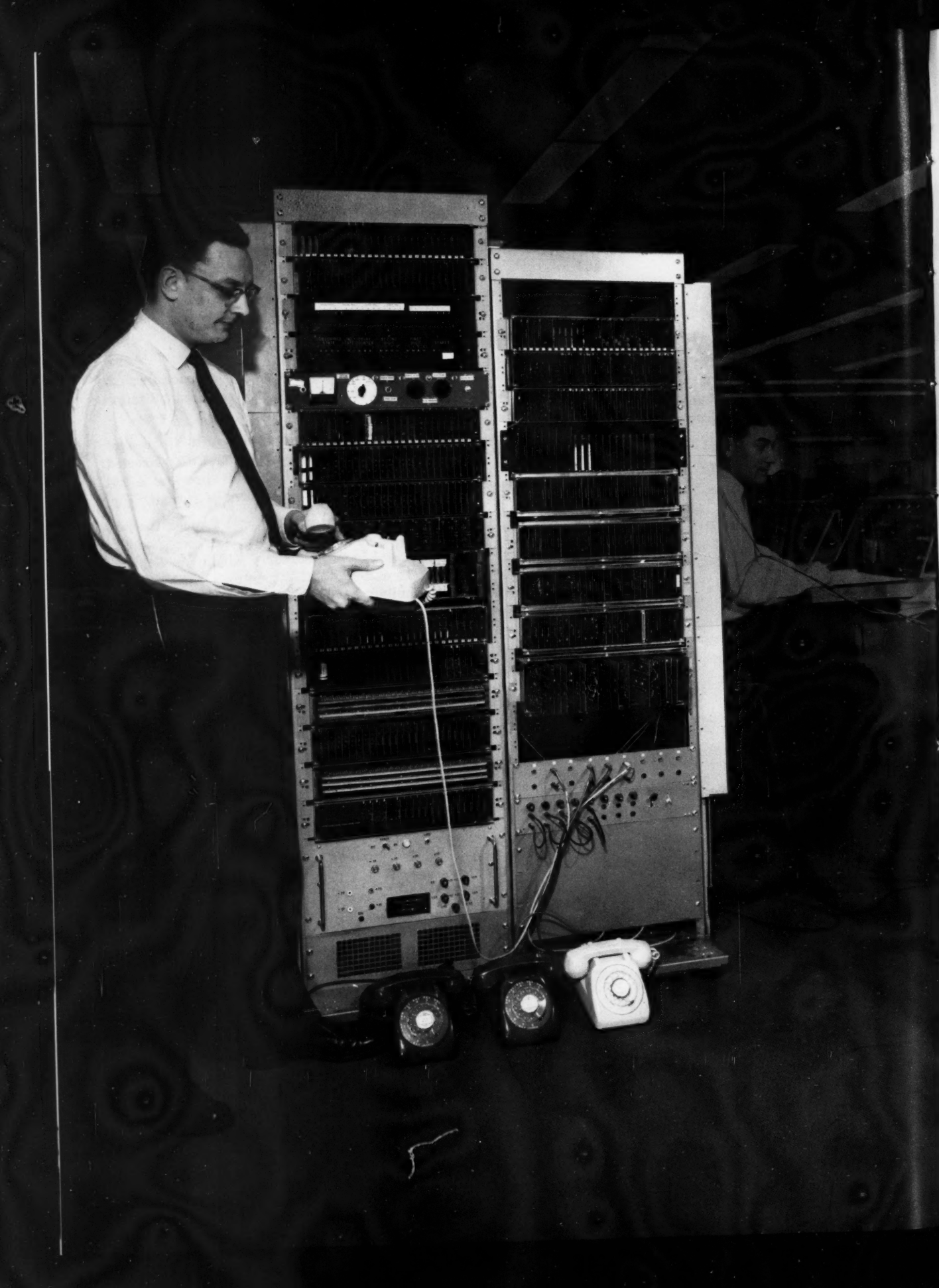


Figure 2. System Logical Circuitry



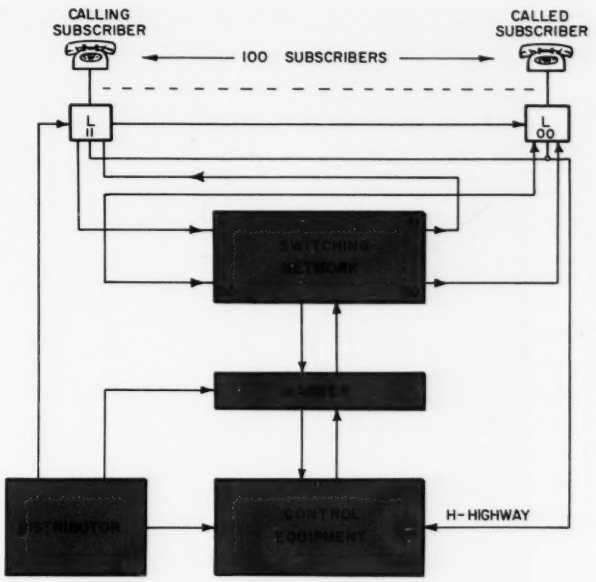


Figure 1. System Block Diagram

A 100-LINE ELECTRONIC PRIVATE AUTOMATIC TELEPHONE SWITCHBOARD

By: John G. Van Bosse

The rapid development of semi-conductor devices has opened attractive possibilities for the use of electronics in automatic telephone switching. Several articles have been published in the Technical Journal* which have described specific applications of this new technique as developed in Automatic Electric Laboratories. The following paragraphs describe an experimental electronic switchboard designed to serve as a private automatic exchange for up to 100 subscribers. The system provides voice-frequency connections between subscribers by employing PNPN silicon diodes in a four-stage network. Control action is performed by centralized equipment which is time-shared by all subscribers.

The Electronic Private Automatic Telephone Switchboard discussed herein is shown in block-diagram form in Figure 1. In the switching network, audio-frequency connections between pairs of subscribers are established and terminated under control of the marker (composed of registers and associated logical circuitry) which in turn receives "connect" commands from the control equipment. The "connect" command to the marker is accompanied by the addresses of both the calling and the called subscribers.

The control equipment collects, modifies, and stores information to be used by the marker. It consists of a ferrite-core memory which contains 100 words of 16 bits (one word for each of the 100 subscribers), a register, and logical circuitry. Since a time-sharing control method is used, a distributor is employed in the system to generate 100 sequential timing pulses, each pulse 160 microseconds in length and the complete cycle recurring every 16 milliseconds.

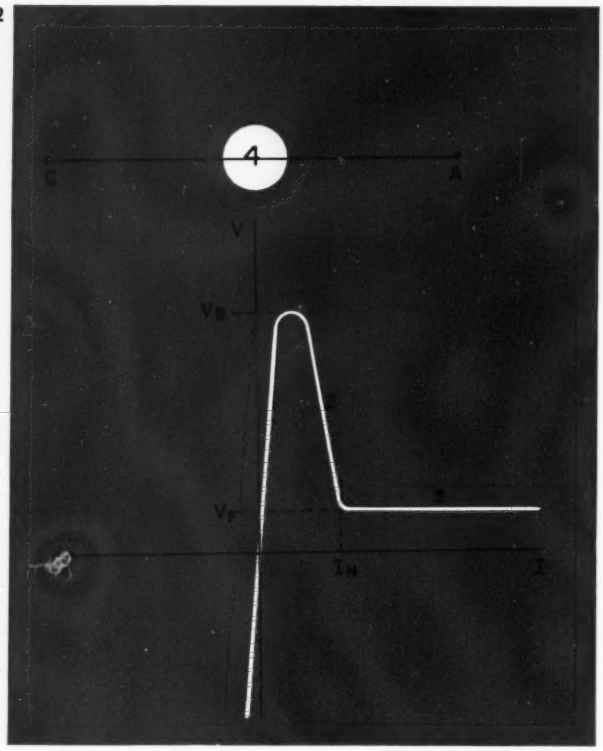
These 100 timing pulses divide the system time-base into 100 "time slots", each associated with one subscriber. During the appearance of a time slot the distributor will address a word in the ferrite-core memory which is read out from the memory into a "P" register (in the control equipment) which now contains information from the subscriber that is 16 milliseconds old. At the same time, the distributor addresses the subscriber's line equipment, and if the subscriber's line-loop is closed, a current-sensing device will produce a signal on the H-highway during this time-slot period.

Electronic Switching, by Richard C. Stiles, January 1959.

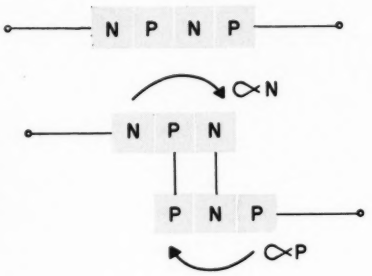
A Fully Automatic Telephone Exchange using Time-Division-Multiplex Technique, by Donald K. Melvin, April, 1959.

Lossless Transmission Circuit for an Electronic Switching System, by L. K. Lugten, July, 1959.

A Ferrite-Core Memory System and Distributor for a Small Electronic Telephone Switching System, by P. E. Osborn, October, 1959.



[A]



[B]

Figure 2. PNPN Silicon Diodes used as Crosspoint Switching Elements

THE CROSSPOINT SWITCHING NETWORK

Crosspoint Elements

As previously stated, PNPN silicon diodes are used as crosspoint switching elements. As can be seen in Figure 2 [a], the voltage-current characteristics of these diodes provide three distinct regions: "off" (1), "on" (3), and "negative impedance" (2). In the "off" region the device will exhibit a large resistance, in the order of a few megohms. In the "on" region it will exhibit a small resistance, in the order of a few ohms—in series, however, with a fixed forward-voltage drop (V_F) of one volt. These two regions are separated by the "negative-impedance" region.

To switch from "off" to "on", the device is subjected temporarily to a voltage in excess of the breakdown voltage (V_B). When in the "on" state, the device will remain there until current is diminished below a critical value, I_H (holding current).

Explanation of these voltage-current characteristics involves visualizing the PNPN device as an NPN and a PNP transistor connected back-to-back, the outside layers functioning as emitters (see figure 2[b]). It can be seen that the device is in the "on" state when the sum of the alphas of both transistors exceeds unity. The alphas are dependent both on current density and on the reverse potential across the center junction, which acts as collector-base junction in both transistors (avalanche multiplication).

Starting in the "off" state, the sum of the low-current alphas is well below unity. Increasing the voltage across the device, the alphas increase because of avalanche multiplication, until their sum reaches unity at the breakdown voltage V_B. Starting in the "on" state, the high-current alphas are sufficiently large to insure their sum being larger than unity. Decreasing the current through the device, however, decreases both current-sensitive alphas until their sum just equals unity at the holding-current level, I_H. When the current is reduced further, the sum of the alphas drops below unity and the device turns off.

The network in which these elements are used contains a number of switching matrices. Each matrix contains a number of horizontal input wires and a number of vertical output wires, and the crosspoint elements are located at the intersections of the incoming and outgoing wires. Since, in the "on" state, elements exhibit a very low impedance between terminals, an incoming wire is effectively connected to an outgoing wire when the crosspoint element at their intersection is turned on.

Network

For simplicity, we show in Figure 3 such a switching network accommodating only eight subscribers (11, 12, 13, 14, 21 — 24), and capable of handling up to four simultaneous connections, but otherwise comparable to the network accommodating 100 subscribers. Black line shows a possible connection between calling subscriber 12 and called subscriber 23. This connection runs through four cascaded switching matrices XA, XB, XC and XD. (Note that the number of the XA switch involved in the connection is determined by the first or "tens" digit identification of the calling subscriber. Likewise XD switch 2 is also involved in this connection, since the called subscriber has a "tens" identification "2".) The marker, during the route-selection period, will determine what XB and what XC switch is available to establish the connection.

At the center of the switching network, the links joining XB and XC matrices pass through junctors (J). (A junctor is identified by a two-digit number, the first digit corresponding to the number of the XB switch and the second to the number of the XC switch that are joined by it.) The junctors serve to maintain an established connection until a "disconnect" command is received by the marker from the control equipment. Such a command is always accompanied by the junctor address, indicating

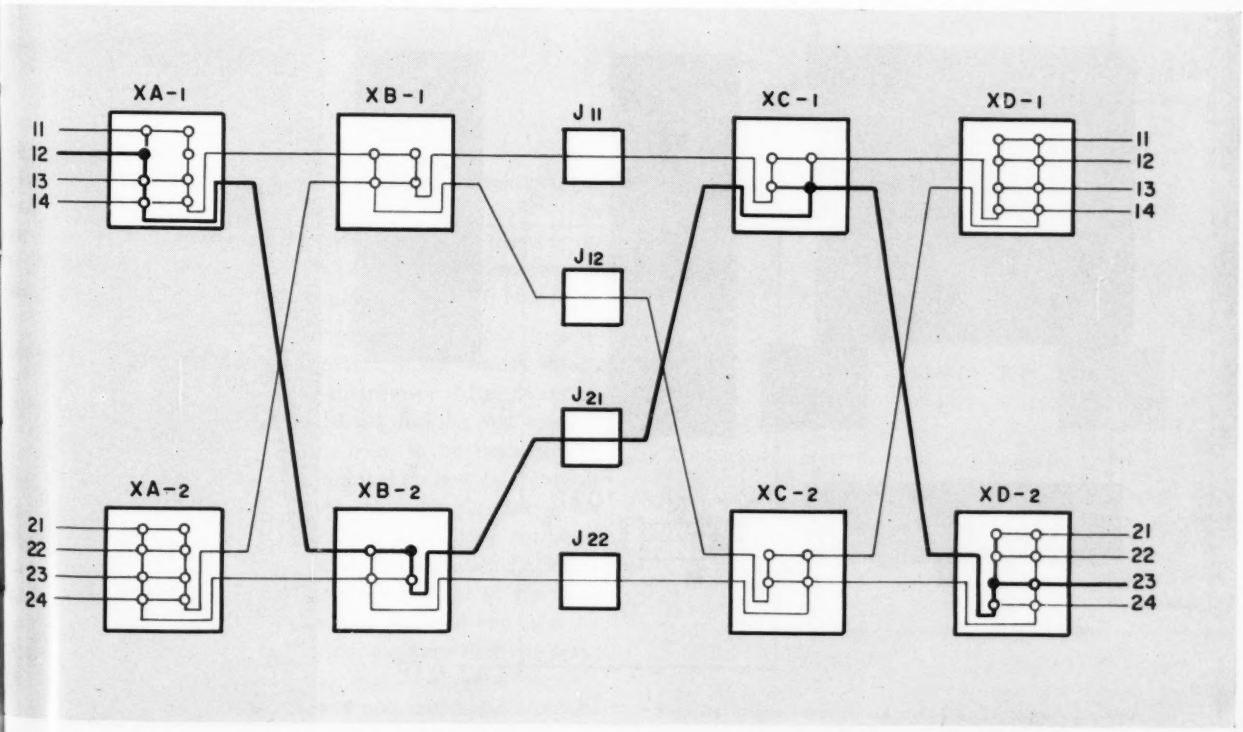


Figure 3. Crosspoint Switching Network accommodating eight subscribers

the connection to be terminated. The connection from calling subscriber 12 to junctor J21 is shown in more detail in Figure 4. Since the switching network exhibits a mirror-symmetry with respect to the center line, the other half of the connection, from junctor J21 to called subscriber 23, involves identical elements. We will assume that the marker has received a request to connect subscriber 12 with subscriber 23, and that at the end of the route-selection period it has determined that the route through XB-2 and XC-1 is available for this connection.

Initially, the junctor (J21) is idle; flip-flop FF-J21 is in state "0" and supplies base current to Q1 which is in saturation, carrying currents from $+V_{BB}$ through resistors R1 and diodes CR1, so the potential P_A is close to ground. Transistors Q2 are "off" and the potentials P_B and P_C of the idle links are also close to ground.

The first step in initiating a connection involves marking the selected links of the route. Every link contains a transistor, Q2, and a resistor, R2. Transistors Q2 are driven by "AND" gate circuits, which in turn are fed from marker outputs. Since subscriber 12 is to be connected to the left-hand side of the network, marker outputs LT-1 (left tens-1) and LU-2 (left units-2) are energized. Since the connection is to be routed over XB-2, the marker output XB-2 is energized; during the marking time, the marker output M is also energized. This activates the "AND" gates and saturates Q2A and Q2B; the voltage at P_B and P_C drops to $-\frac{1}{2} V_B$.

A little later the "AND" gate to the "set" input FF-J21 is energized by the addressing signals XB-2 and XC-1, and the connect command "C" from the marker. The flip-flop moves to state 1, cutting off Q1, and the voltage at P_A starts rising toward $+V_{BB}$. When the voltage reaches $+\frac{1}{2} V_{BB}$ the PNPN diode in XB2 breaks down, and the voltage P_B rises. When this voltage reaches the value $+\frac{1}{2} V_B$, the PNPN diode in XA-1 breaks down and the voltage at P_C rises. When this voltage reaches ground, CR-2 starts conducting. (Note that during the marking and connecting actions, the potentials at P_A, P_B, P_C are restricted between the values of $+\frac{1}{2} V_B$ and $-\frac{1}{2} V_B$. Since the potential of both idle and busy links in the system remains within a few volts from ground,

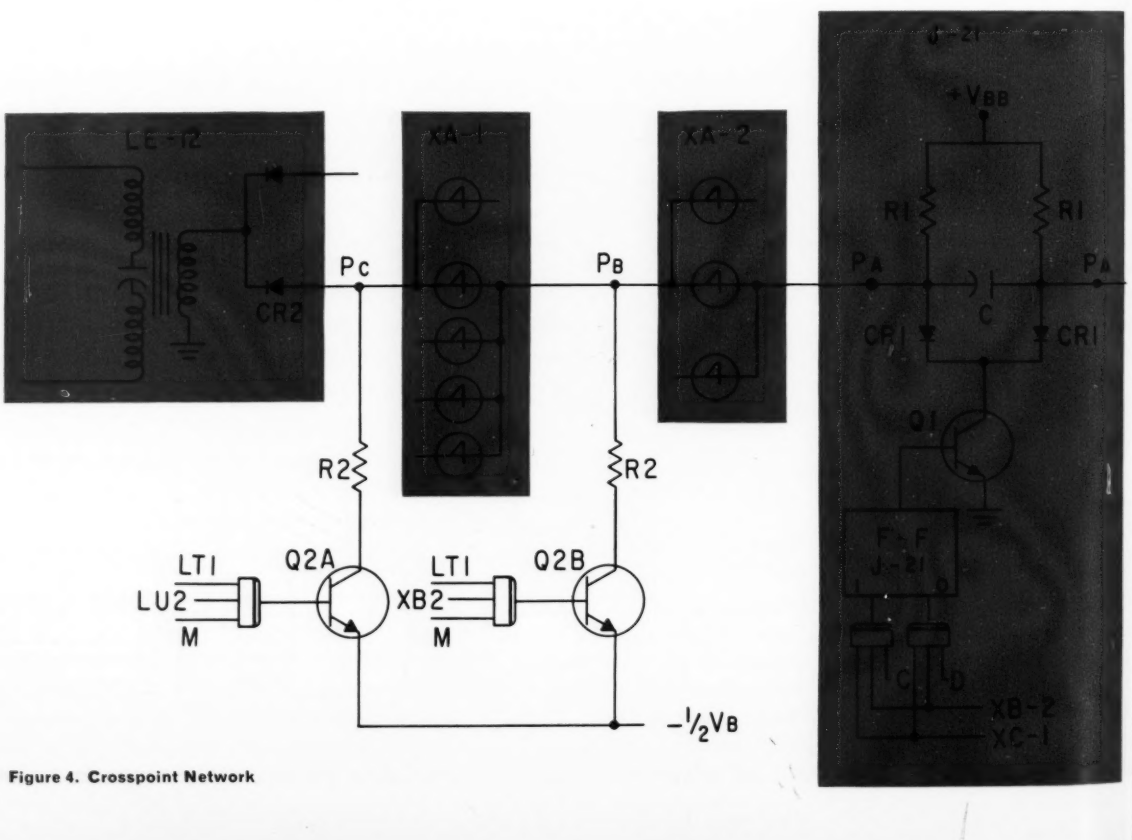


Figure 4. Crosspoint Network

all PNPN diodes connected with one terminal to the path being established are subjected only to voltages in the order of ½ V_B, and therefore do not turn on spuriously.)

The marker next suppresses the marking command M; Q2A and Q2B turn off. A connection is now established from J21 to the line transformer of subscriber 12 through the PNPN diodes in XA-1 and XB-2. At the same time a similar process initiates the connection in the right-hand half of the network between J21 and the called subscriber. The four-layer diodes in both branches receive sustaining current through resistors R1. Voice-frequency currents are carried from one side of the network to the other through capacitor C in the junctor circuit.

This situation continues until the marker receives a "disconnect" order, which is accompanied by the address of the junctor that held the connection. In our case, marker outputs XB-2 and XC-1, addressing junctor J21, are energized. When the disconnect signal "D" appears, the "AND" circuit feeding the reset input of FF-J21 is energized, and the flip-flop reverts to state "0". In this state, Q1 is turned on and saturates. Since the sum of the forward-voltage drops of Q1 and CR-1 is smaller than the sum of the forward-voltage drops of the PNPN diodes in XA-1 and XB-2, the sustaining current through R1 is diverted from the PNPN diodes to CR-1 and Q1. Consequently, the PNPN diodes return to the "off' condition, terminating the connection.

CONTROL EQUIPMENT

The Ferrite-Core Memory

In the first part of this article we touched lightly upon the control equipment, which contains a ferrite-core memory. Figure 5 shows the relation of this memory to the control equipment. As can be seen, the core memory contains 100 words (one per subscriber) of 16 bits each.

As shown in Figure 5, all words are read out sequentially into the "P" flip-flop register (in the control equipment), under command of the distributor. After read-out, a word is modified in the logical net and the new word is written back into the core memory to be read out 16 milliseconds later. A word is modified by new information generated by the subscriber who, through his dial or his hook switch, controls his line-loop condition; line-loop condition is sensed in the line equipment, which causes a signal, "H", to be fed into the logical net at the time a closed loop condition is present. A word can also be modified under command of the marker; this happens, for instance, when the marker has received a connect request from a calling party, and now stores the numbers

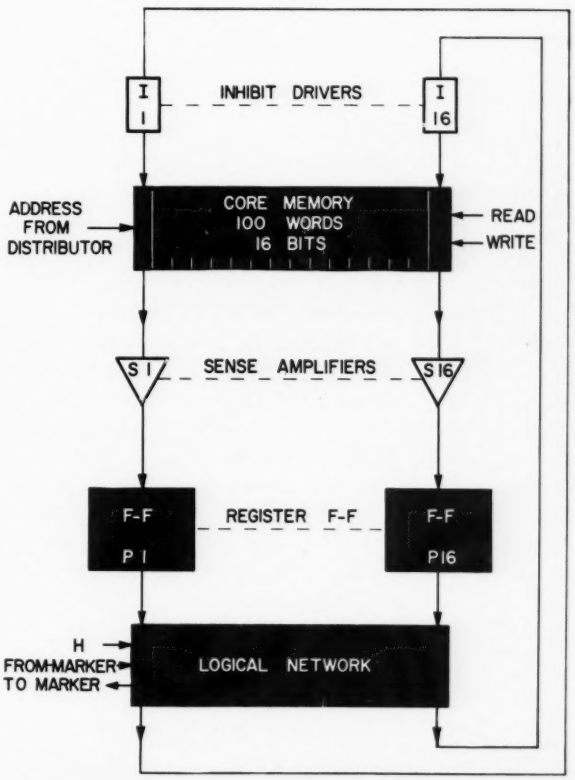


Figure 5. Control Equipment showing "Flip-flop" Register

of both the calling and the called parties. When the word corresponding to the called party is read out (which is evidenced by a parity of the called-party address, as stored in the marker, and the distributor-generated address) this word is changed to indicate that the corresponding subscriber now is a called party.

The 16-bit word can be divided into four parts of four bits each. Bits 1-4 indicate the state of a subscriber (in our present system there are twelve subscriber states, e.g., at rest, dialing, connected as calling party, connected as called party, etc.).

Bits 5-8 contain information on the subscriber line-loop condition:

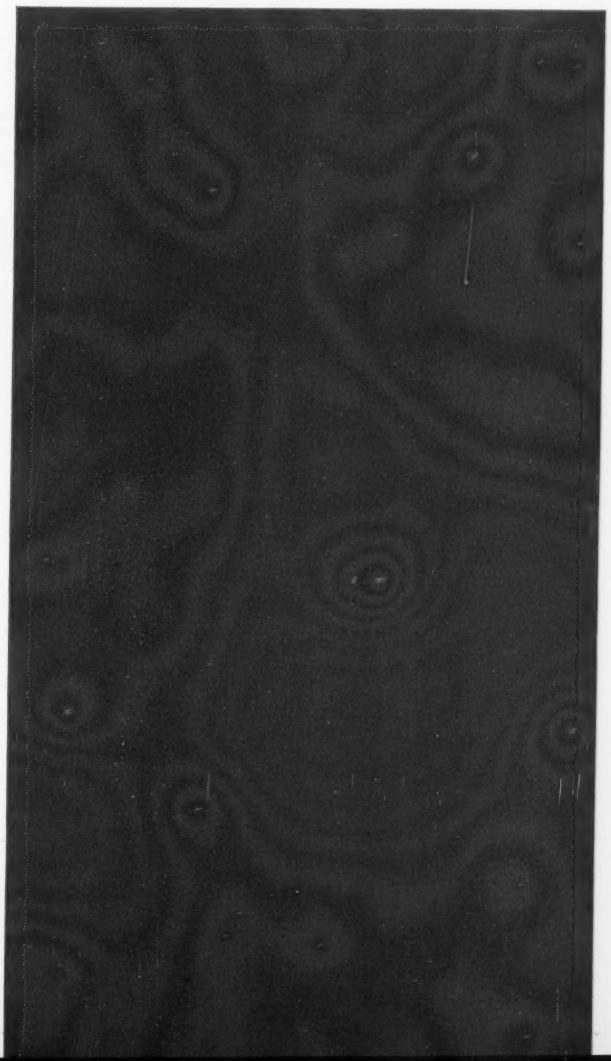
Bit 5 indicates whether the line-loop was open or closed at the time the word presently read-out was written, 16 milliseconds ago. Comparison of this "last look" with "H" determines whether a change in line-loop condition has occurred (a reversal in line-loop condition may mean the beginning, or the end, of a dial impulse, or the lifting or replacing of the subscriber's handset).

Bits 6-8 form a counter chain, determining how many cycles ago the line-loop condition was last changed. The counter is reset to count "1" at every loop-reversal, and steps up from there every succeeding cycle as long as there is no loop reversal. This information is needed to differentiate between the short makes and breaks generated by a spinning dial (which are in the order of 40-60 milliseconds) and makes and breaks of sufficient length for the counter to reach its highest count, "7", indicating 112 milliseconds since the last loop reversal. A make-after-break of 112 milliseconds is interpreted as the inter-digital pause between two trains of dial impulses. A break-after-make of 112 milliseconds indicates that the subscriber has replaced his handset on the hook.

The meaning of bit groups 9-12 and 13-16 depends on the subscriber states as coded in bits 1-4. When bits 1-4 indicate that a subscriber is dialing, bit group 9-12 collects and stores the first dialed digit and bit group 13-16 collects and stores the second dialed digit. In this way the address of the called party is made available to the marker. On the other hand, when bits 1-4 indicate that a subscriber is connected to the switching network, either as a calling party or as a called party, bit group 9-12 indicates the number of the XB switch and bit group 13-16 indicates the number of the XC switch involved in the connection. In this way, the marker is informed (when in the 16 millisecond route-selection cycle during which the words corresponding to every subscriber appear once in the "P" register) about all connections already in progress, and can select a remaining free route for the new connection to be established. In addition, this information, which is in effect the junctor address, is used by the marker to terminate the appropriate connection when bits 1-4 show the subscriber to be in the "waiting-to-terminate" state.

Having formulated the meaning of the various bit positions in the 16-bit word, the rules for modifying a word can be deduced by straightforward Boolean techniques and implemented in a logical network feeding the 16 digit-inhibit drivers of the ferrite-core memory.

JOHN G. VAN BOSSE joined Automatic Electric Laboratories in 1957. He was assigned to the position of supervisor on the development of an electric telephone switching system. Previous to joining AE, he served two years as a radar systems engineer in the Laboratories for Electronics of the Royal Netherlands Navy. Mr. Van Bosse received his engineering degree from the Institute of Technology, at Delft, Netherlands. He is an associate member of the I.R.E.



Signaling

Since the ferrite-core memory in the control equipment contains a storage location for every subscriber, any subscriber may start dialing immediately after lifting his handset; therefore, no provision is made for dial tone.

Ringing and ring-back tones are provided from the junctor involved in a connection, and are under control of a second, "ringing", flip-flop associated with the junctor. This flip-flop is set to state "1", thereby gating a ringing signal on the connection, when it is first established; this signal is transmitted through the crosspoint network to both calling and called subscribers. When the called subscriber lifts his handset, his state bits 1-4 in the ferrite-core memory are changed from indicating "called party, not answering" to "called party, answering." Since the address of the junctor involved in the connection has been written in bit positions 9-16 of the word corresponding to that party, it is possible to reset the proper ringing flip-flop, thereby terminating the ringing.

It is not practical to drive conventional electromechanical ringers with the signal levels that can be transmitted in the crosspoint network. Therefore, each telephone instrument is equipped with a transistor amplifier which is energized whenever the telephone handset is on hook. Ringing signals are thus amplified, and are fed into the receiver capsule of the handset, producing a tone signal of ample loudness.

CONCLUSION

In the near future, electronic switching systems will emerge from the laboratory to the field-test stage. Electronic techniques will certainly bring about greater versatility and size reductions in telephone equipment, when compared to present-day electromechanical systems. Of course, operational reliability will have to be proven in field tests, and will depend in a large measure on the reliability of the individual semiconductor components used.

NEW NEGATIVE-IMPEDANCE REPEATER

permits accurate impedance matchin

By: R. P. Dimmer

Figure 1. The Type AT-6 Repeater

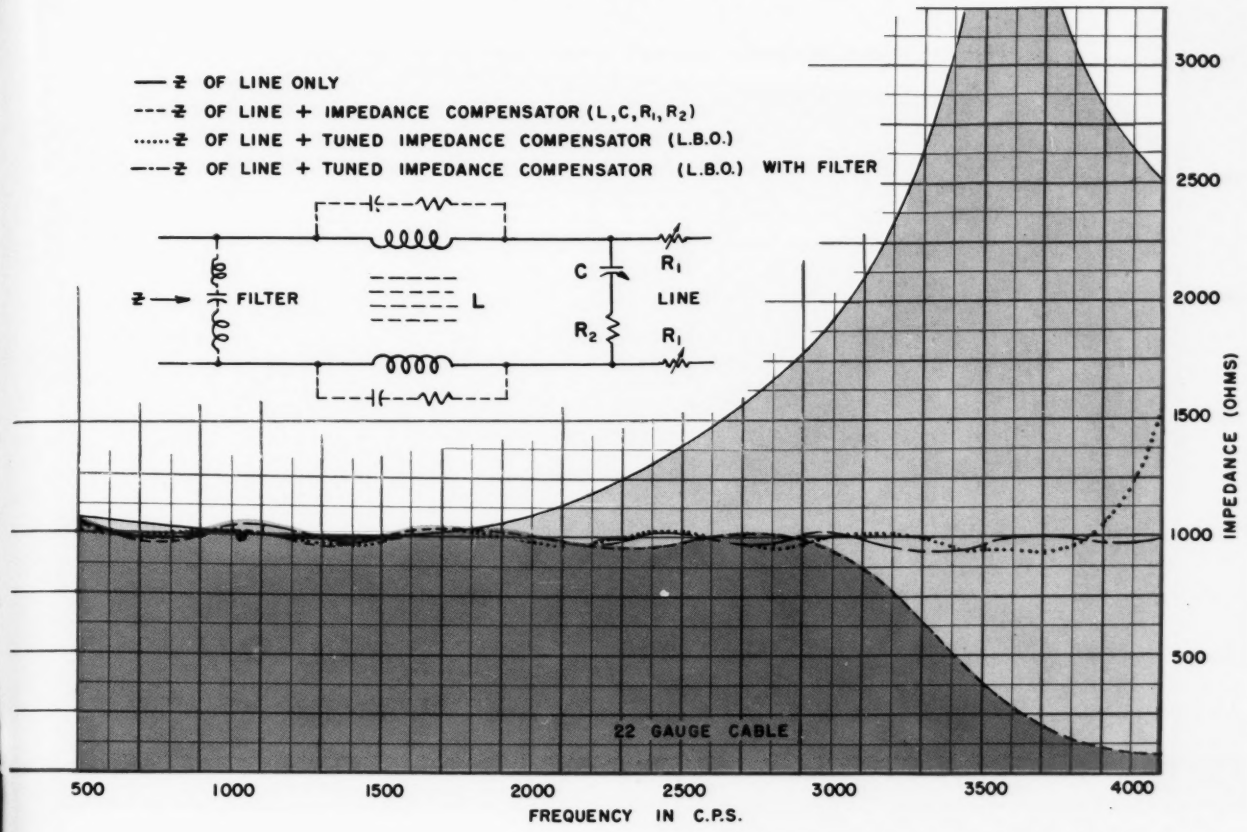


Figure 2. Impedance of Loaded Cable at 0.5 End Section

Within the last five years, transistorized negative-impedance repeaters have been widely accepted in the telephone plant, because of their low operating and maintenance cost. These repeaters, when properly installed, have given creditable performance in improving transmission, on circuits (usually not exceeding 25 miles in length) connecting a subscriber to his local telephone office, or interconnecting a group of offices within an exchange area. Sometimes, however, present types of negative-impedance repeaters emphasize a problem called "talker echo."

When a subscriber makes a call his speech-energy travels over the telephone line to the called instrument. If the line and the instrument do not have a good impedance match, some of the speech-energy will be reflected back to the calling subscriber, and if an appreciable time is required for this travel to the distant instrument and back, the speech-energy will be received as an echo ("talker echo"). This noise creates an impression that the called subscriber is trying to interrupt.

Talker echo increases as "return loss" decreases (return loss is a measure of the extent to which the line impedance departs from that of the standard office impedance; it is measured in decibels). Our objective is therefore to obtain the highest practicable return loss, since more energy is then transmitted and less is reflected to the sender. If the impedance of the line were perfectly matched to that of the distant "load," all the energy transmitted would be absorbed in the "load" equipment at the distant or receiving end of the circuit. However, such ideal conditions do not exist because the transmission line itself contains minor impedance irregularities and therefore does not match perfectly the sending and receiving devices at all frequencies.

To illustrate this point let us look at the characteristic impedance of a loaded cable pair at the 0.5 end section, as shown in Figure 2. This pair has a resistance component which increases with frequency, but with a very small negative reactance component; the compromise network in the usual intertoll terminating circuit has a resistance which remains constant at all frequencies. When a suitable repeat coil is used for proper matching at 1000 cycles, the return loss of the compromise network against the toll connecting trunks is good at 1000 cycles —frequently in the order of 20 db. Since the resistance component of the trunk impedance increases with fre-

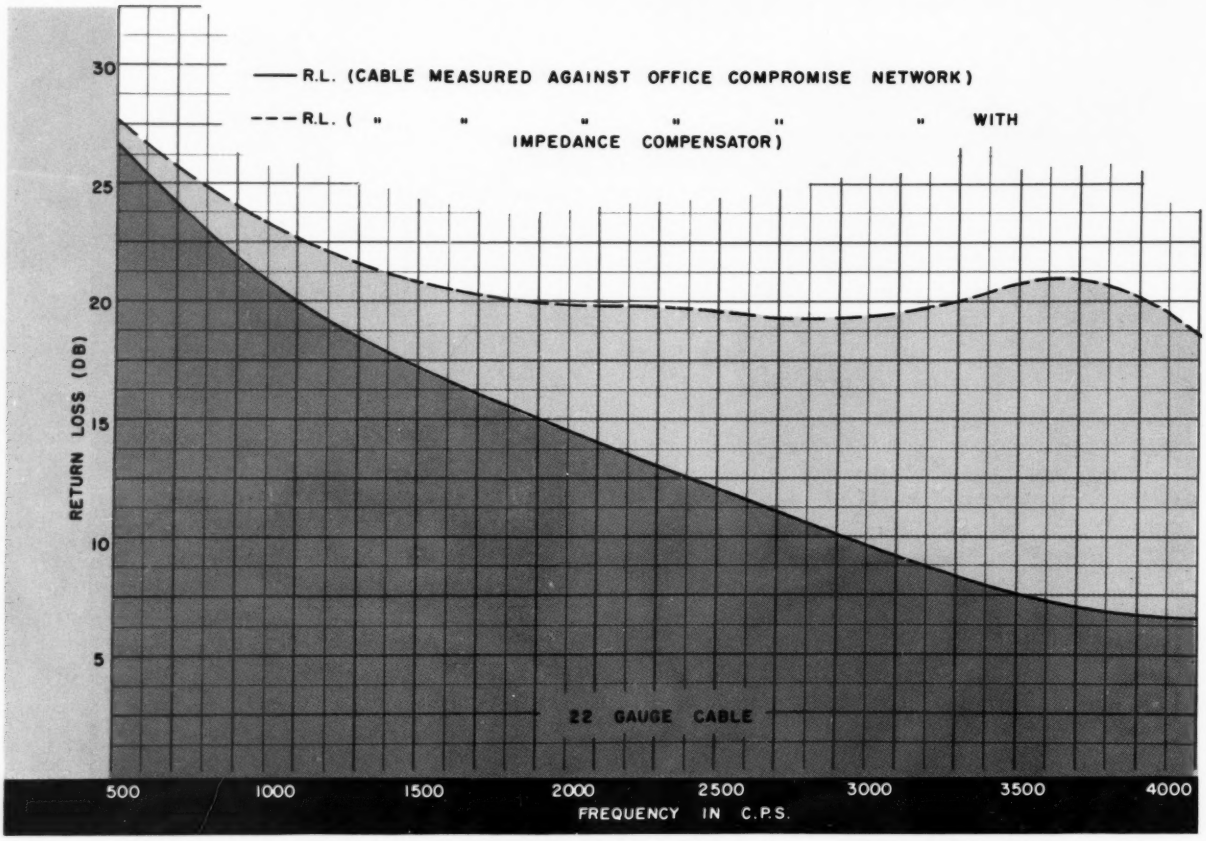


Figure 3. Return Loss Characteristic of Loaded Cable

quency, however, the return loss against the same fixed value of the compromise network deteriorates with increasing frequency—to what extent will depend upon the cutoff frequency of the loading section; with H88 loading, the 3000-cycle return loss is in the order of 9 db, as shown in Figure 3. To add a negative-impedance repeater of any of the existing types to an end-office with such a network would deteriorate this return loss even more because of the small irregularity that the repeater itself would add. It is for this reason that a repeater of this type is rarely used alone near this type of office; to substantially improve this return loss a conventional impedance compensator is used with the cable pair to keep its impedance from changing significantly over the frequency range from 1000 cycles up.

An impedance compensator most widely used in telephone practice incorporates a conventional 44 MH load coil and build-out-capacitance as shown in Figure 2. The capacitor builds out the loading end section of the cable to approximately 0.8 section for which the resistance component of the impedance is substantially uniform over the frequency range up to a high fraction of the cutoff frequency, and the reactive component becomes increasingly negative with frequency. Since an inductance has a positive reactance to frequency, the addition of a coil of suitable magnitude at this point in the loading end section tends to cancel the negative reactance over the frequency range in question, resulting in an impedance substantially resistive and of fairly uniform value between 1000 cycles and a frequency corresponding to about 0.85 cutoff.

The impedance on the office or drop side of a conventional impedance compensator remains primarily resistive over the voice-frequency band; consequently, it is possible to add, at this point, a negative-impedance repeater which uses *only* a resistance for its gain adjustment network. By making this resistor adjustable, a simple gain adjustment is obtained in the network. Since this type of gain adjustment does not involve phase angles, it matches closely the resistive line, and as a result, the overall frequency response of this combination becomes smoother than with former repeaters. Also, because of the use of the compensator, the return loss at the upper end of the frequency band (3000 cycles), remains in the order above 20 db when compared under similar conditions.

The merits gained by the use of an impedance compensator in conjunction with a negative-impedance repeater must be considered in future design.

Figure 4. Eight AT-6 Repeaters Mount on One Shelf

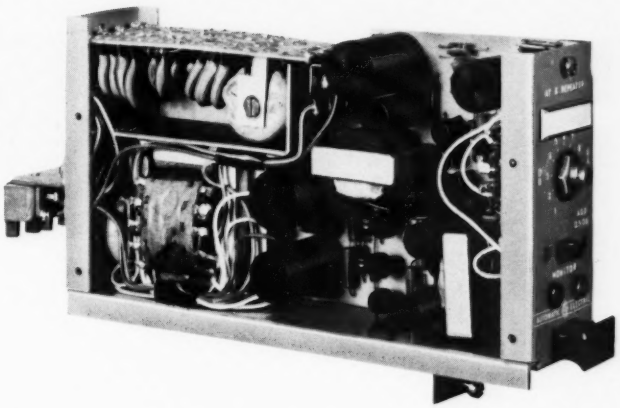


Figure 5. Inside View of Repeater, showing Component Mounting Details

Oscillation in Idle Condition

The basic impedance compensator will work satisfactorily with a combination series-shunt repeater on the drop side when the circuit is in the idle condition. During the use condition the series section of the repeater may "sing". Figure 2 shows how the impedance of a simple compensator drops at the high frequency end of the band. Because a series negative-impedance repeater is short-circuit unstable, oscillation will occur as a result of this drop in impedance. To correct this unstable condition the compensator is resonated at 3500 cycles. Figure 2 further shows how this resonance keeps the impedance constant to about 4000 cycles before a change occurs. Using this tuned compensator, the series section of the repeater will be stable in the use condition but the shunt section will oscillate in the idle condition, since this section is open-circuit unstable and will oscillate when its termination impedance rises. This oscillation is corrected by a series resonant circuit (peaked at 5000 cycles) and bridged on the line to keep the line impedance substantially constant up at this range. Figure 3 shows how an impedance compensator keeps the return loss of a typical loaded facility high and substantially constant over the frequency band in question.

Type AT-6 Negative Impedance Repeater

The new Type AT-6 Negative Impedance Repeater is shown in Figures 1 and 5. The unit, 2 inches wide and 10¼ inches deep (overall) occupies a shelf height of 5¼ inches. Up to eight repeaters can be mounted on a single shelf for the 19-inch relay rack, as shown in Figure 4, or ten repeaters can be mounted on a shelf for the 23 inch rack. The AT-6 utilizes the same shelf and shelf jack which has become so popular with the AT-2 and AT-3 repeaters. The repeater slides on a track to engage an 8-point shelf jack, factory adjusted to switch both sides of the line straight through when a repeater is removed. This feature permits rapid replacement of a defective repeater without interrupting conversation.

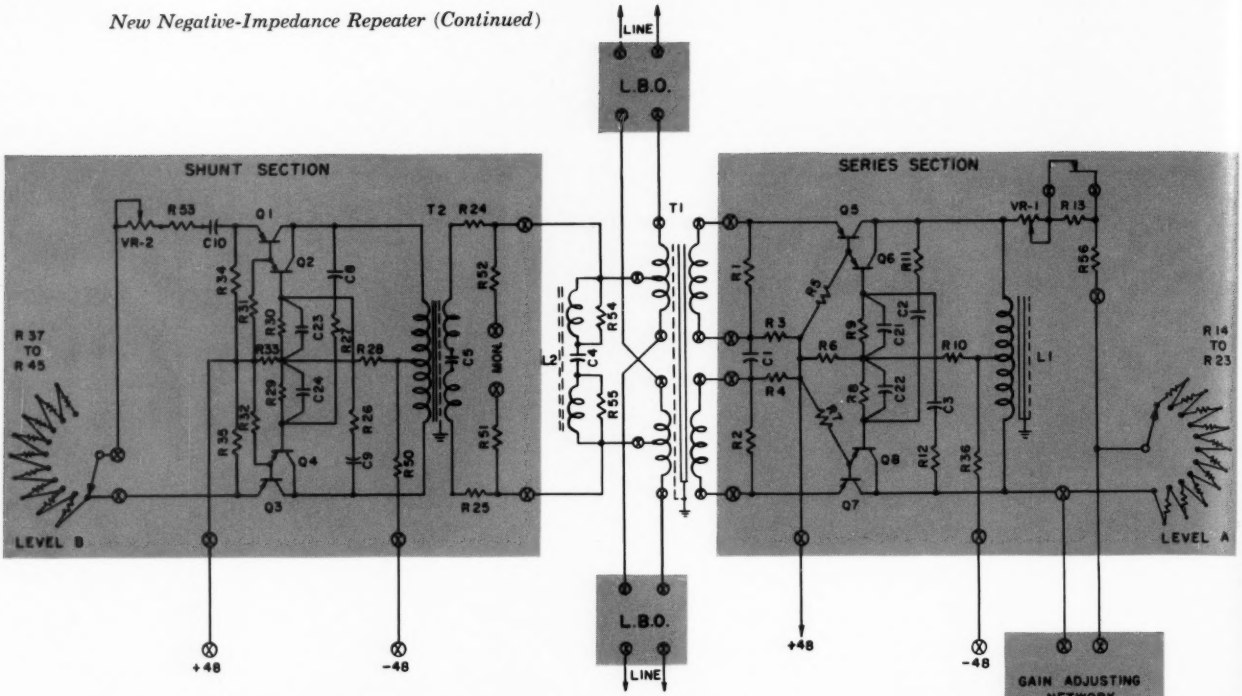


Figure 6. Circuit of the AT-6 Repeater

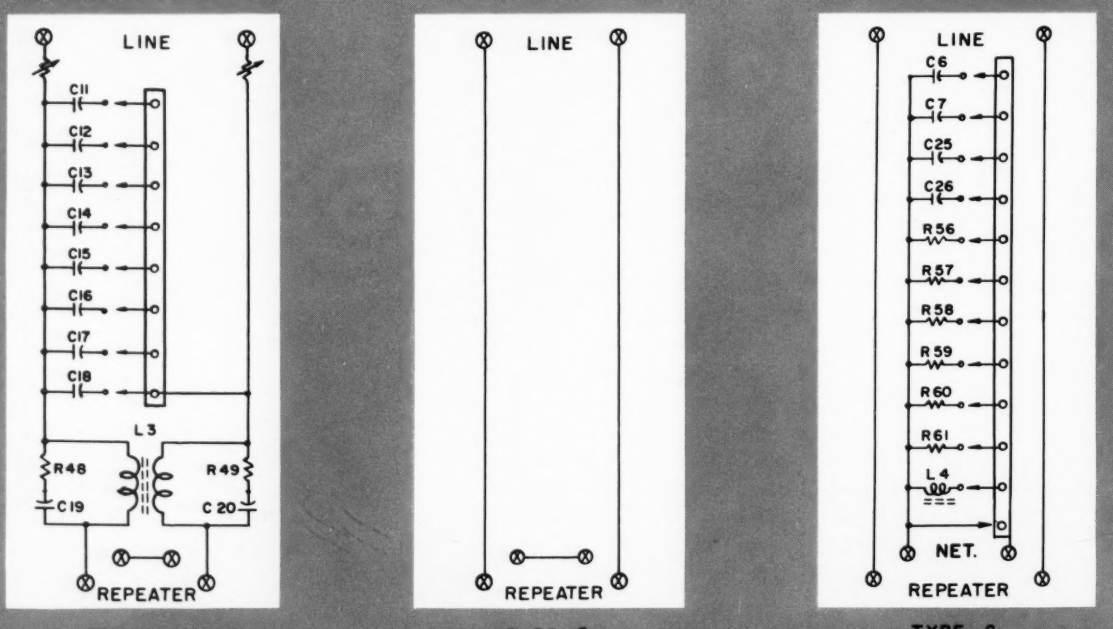


Figure 7. Line and Gain Adjusting Network of Repeater

The AT-6 will afford the following improvements to the telephone plant where repeaters are required:

- It is a combination series and shunt repeater in one case; this results in 50% saving in space required for mounting.
- The unit is fully transistorized. This saves space and power, and offers many other advantages.
- It uses a simple resistance-adjustable network, controlled from the front panel. This greatly simplifies the gain adjustment by eliminating strapping tables, and increases the accuracy of the repeater's impedance, since variations in impedance angles are eliminated.
- In the AT-6 repeater the use of screws as connecting elements between components in the network eliminates strapping and the need for soldering irons, and also reduces the chance of making errors in strapping.
- The repeater may be tested for gain in a standard test circuit without actually connecting to the facility. The gain thus obtained will be very close to that obtained in the facility.

Circuit

The circuit of the AT-6 Repeater, shown in Figure 6, contains a series and a shunt section which are isolated from the telephone circuit through transformers. Figure 7 shows the circuits of the Line Build Out (LBO) and gain-adjusting networks which are added in accordance with the facility encountered. Low frequency correction is afforded by adjustment of the ratio of series to shunt section gains. The repeater has two switches on the front panel, which permits adjustment of gain between 0 and 12.5 db in 0.5 db increments. The front panel also contains monitor test connections and a card holder for identifying the circuit on which the repeater is connected.

Amplifier

The AT-6 amplifier section and the LBO and gain-adjusting networks are assembled on single-sided printed wiring boards. The input transformer is mounted separately from the amplifier section. Strapping on the LBO and gain-adjustment networks is accomplished by tightening screws which contact the printed wiring board. This eliminates the use of a soldering iron and necessitates only the use of a conventional screwdriver.

The AT-6 uses eight PNP transistors (four in each section); the use of this circuitry permits interchangeability of transistors without the need for recalibration. It also reduces the characteristic of aging or gain degradation which sometimes occurs after a few years of operation when single transistors are used.

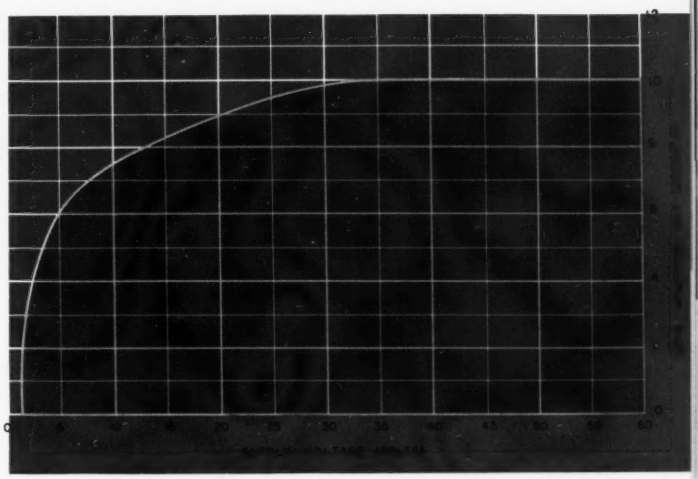


Figure 8. Repeater Performance vs. Supply Voltage

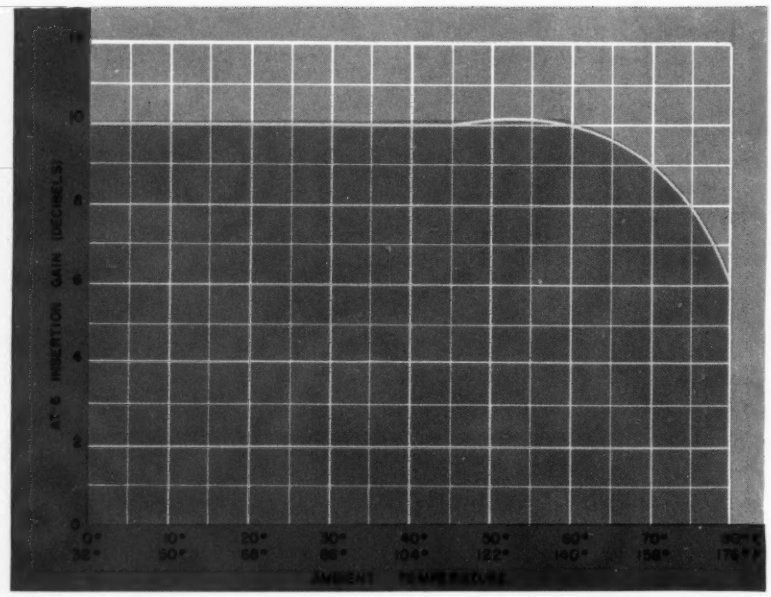


Figure 9. Effect of Temperature Changes on Performance of Repeater

Performance

The AT-6 Repeater consumes approximately 1.7 watts, using the conventional 48 volt telephone exchange battery. With such small power consumption, heat radiation is not a factor; consequently, fans or air-circulating equipment are not required. Figure 8 shows that the supply voltage is not at all critical; in fact, the gain of the unit remains constant with a supply voltage variation between 34 and 60 volts; even at 3 volts, the gain of the repeater drops only to approximately one-half.

In all applications the AT-6 can provide its maximum gain when installed somewhere in the middle third of the line facility; when installed as a terminal repeater its gain is limited to about 70% of the loss of the line, with 6.0 db as maximum. When used in a midpoint application, gain equal to 75-85% of the loss of the line may be obtained, with 12.5 db gain as the maximum. Advantage may be taken of this midpoint behavior by installing these units along the middle third of the line (possibly mounted on poles) and furnishing supply voltage from either of the end offices, by using a spare pair in the cable. The AT-6 Repeater has a very significant merit in such applications, in that changes in supply voltage cause only small changes in the gain provided, as shown in Figure 8. Reduction in supply voltage affects only the output (overload) capabilities of the unit. This effect generally causes little difficulty, because as the repeater is installed further from the office (with supply voltage supplied from the office), its input signal is also reduced; consequently, overloading rarely occurs. The AT-6 is capable of handling outputs from signals normally occurring in telephone practice, without compression or distortion.

The AT-6 Repeater can be operated satisfactorily up to ambient temperatures of 140°F (60°C) before gain degradation occurs as shown in Figure 9. Above 60°C the gain of the repeater begins to drop; it reaches zero somewhere above 185°F (85°C). In most applications these effects are of no significance, but in pole-mounted repeaters, for example, where temperatures of 60°C might be exceeded, it is well to consider the use of air circulation techniques in the design of repeater enclosures.

Application

The AT-6 Repeater may be used on facilities containing loaded or non-loaded cable or a combination of both. If only loaded cable is present an impedance compensator or LBO would be connected to each side of the line terminals of the repeater for midpoint application. In terminal application the office side of the repeater would have a dummy LBO network (see Figure 7).

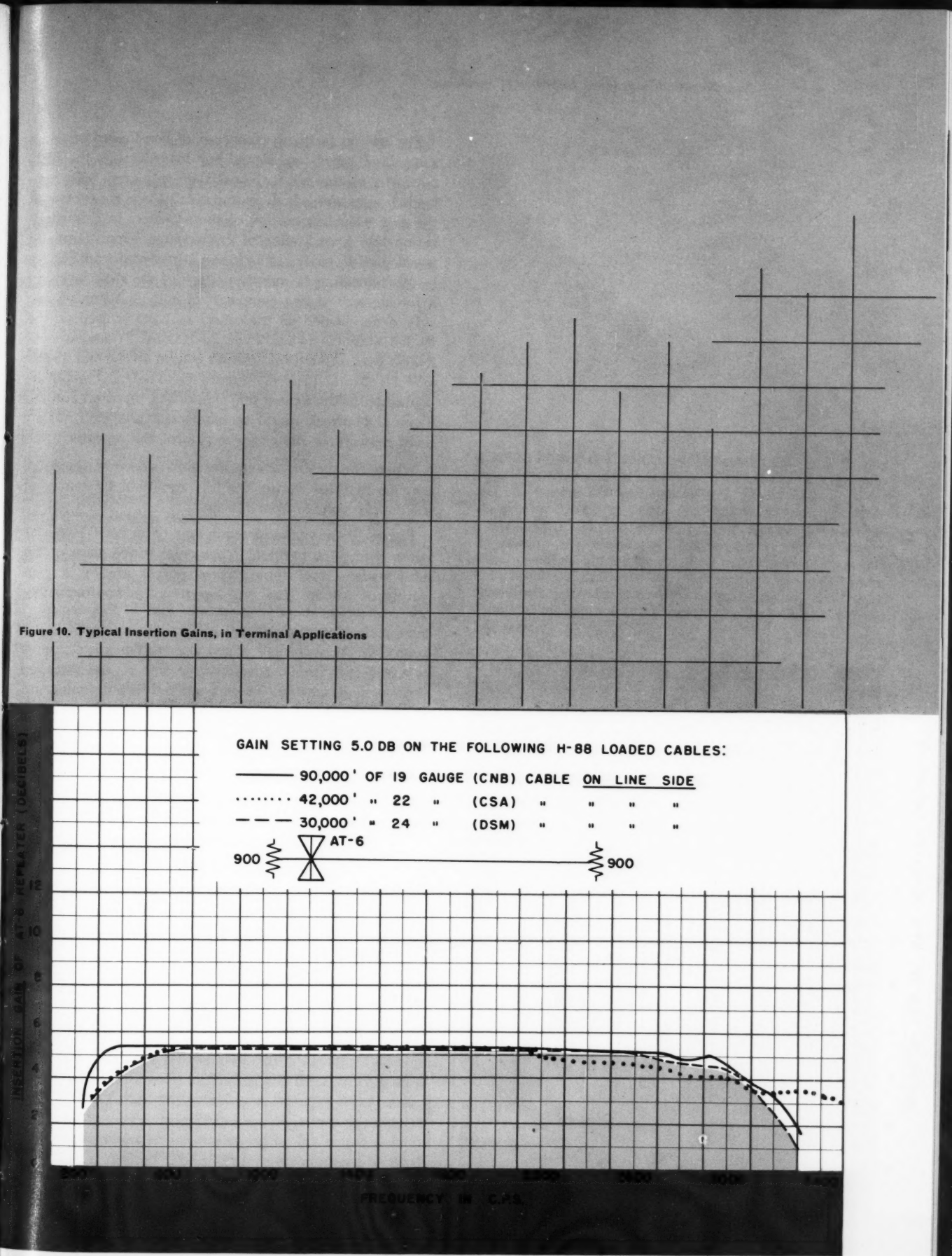

GAIN SETTING 5.0 DB ON THE FOLLOWING H-88 LOADED CABLES:
90,000' OF 19 GAUGE (CNB) CABLE ON LINE SIDE
42,000' " 22 " (CSA) " " " "
30,000' " 24 " (DSM) " " " "
AT-6
900
900
INSERTION GAIN OF AT-6 REPEATER (DECIBELS)
FREQUENCY IN C.P.S.

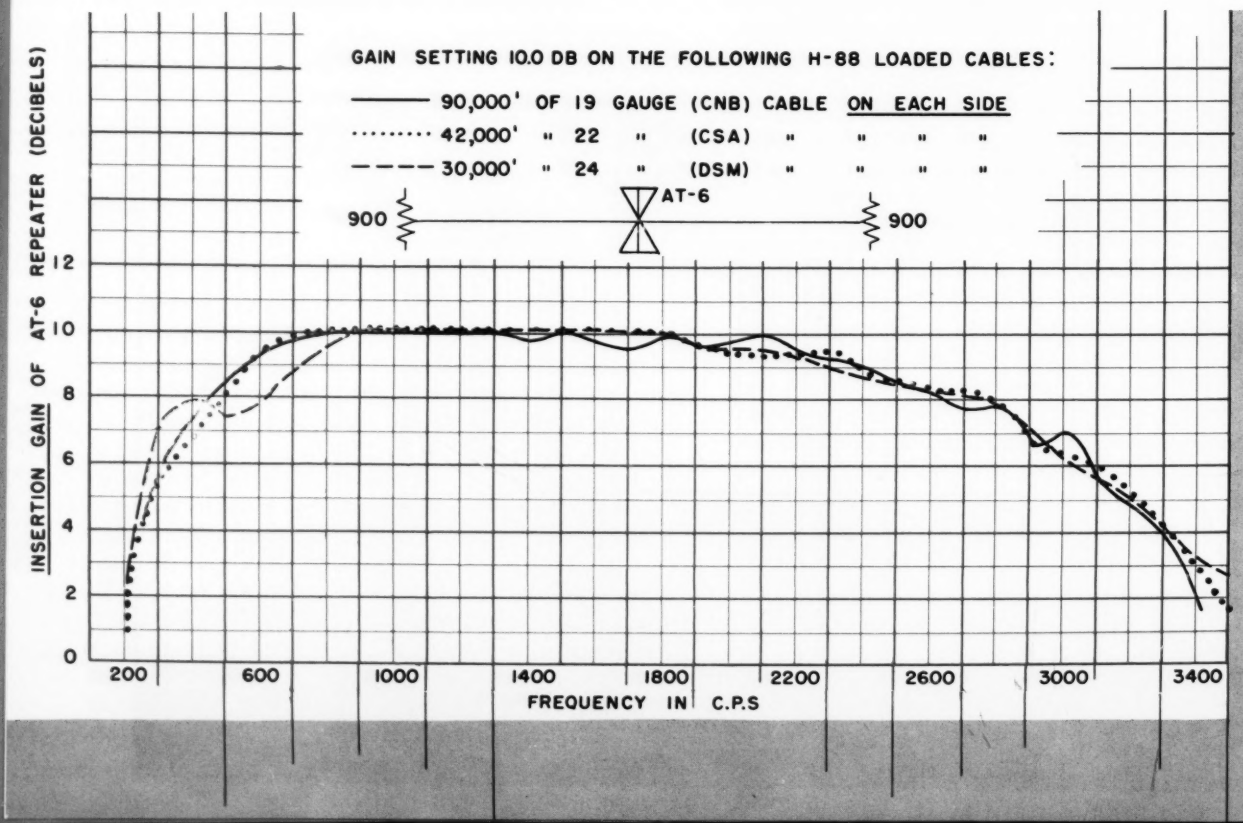
Figure 10. Typical Insertion Gains, in Terminal Applications

For use on facilities composed of non-loaded cable or a combination of loaded and non-loaded cable, the LBO networks in the AT-6 Repeater are replaced with non-loaded networks which automatically are connected to the gain adjusting section of the repeater. In this application the shunt section of the repeater, which normally is not used in these applications, is removed from service by disconnecting its supply voltage at the shelf jacks. In a foreign-service line composed of a loaded line on one side, a non-loaded on the other, an LBO is used on the loaded side (Network Type A—Figure 7) and a non-loaded gain adjustment network is used on the non-loaded side (Network Type C—Figure 7). The LBO would be connected in the loaded line side of the repeater, and the Type C Network would be connected as a gain adjustment network in the series section of the repeater.

Where the maximum repeater gain is desired, the AT-6 may be disabled during the idle condition by removing the supply voltage from the unit.

Figure 10 shows the insertion gain of an AT-6 Repeater when used as a terminal repeater on three sizes of the most widely used cable. These curves are for a gain setting of 5.0 db. The repeater provides approximately

Figure 11. Midpoint Application of an AT-6 Repeater



the same gain for these various sizes of cable with slight differences at the low- and high-frequency ends. The LBO unit used to compile these curves was adjusted for 0.8 end section (recent development work indicates that upper-frequency improvement will result when this is increased to 0.95 end section). The curves in Figure 10, using resistance termination, are quite smooth; however, in actual use a certain degree of curve variation will occur when telephones are used as terminations.

Figure 11 shows the same repeater in a midpoint application on a longer circuit. The gain setting of the repeater in this case is 10.0 db. The upper-frequency end of this curve can be improved somewhat by changing the end section adjustment to 0.95.

Installation

The installation techniques used for an AT-6 are somewhat different from those used for conventional negative-impedance repeaters. Before placing the AT-6 into service on loaded facilities it is necessary to adjust the LBO section to the particular facility.

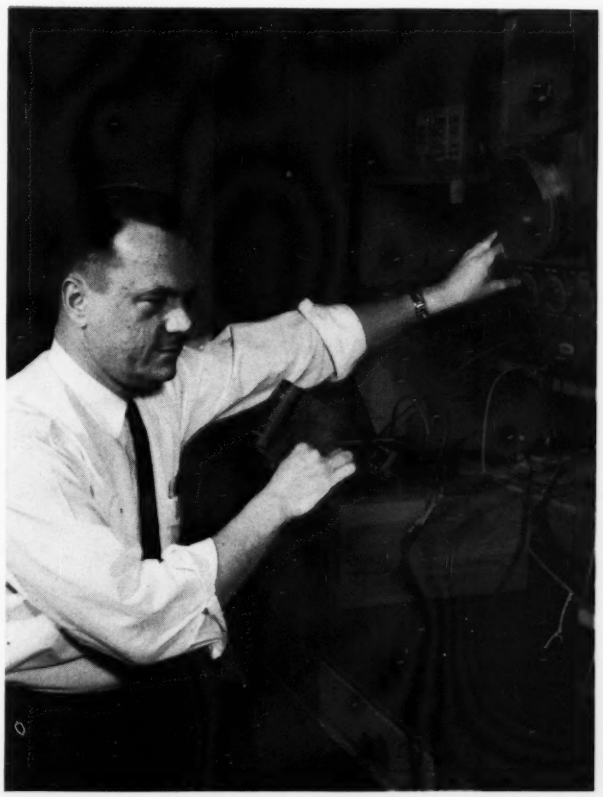
Adjustment of this LBO may be accomplished by the use of a table contained in the instruction booklet, or a more precise adjustment may be obtained by actual measurement. In this measurement the AT-6 Repeater is connected to the facility and an impedance or return-loss measurement set is connected to the repeater side of the LBO. By adjustment of components in the LBO a most desirable flat return loss or impedance characteristic can be obtained.

The AT-6 installer's set is an ideal instrument for the proper installation and adjustment of this repeater. This instrument permits the following measurements:

1) Gain test of AT-6 in standard circuit.
2) Gain test of present AT-2, AT-3 in a standard circuit.
3) Insertion gain of repeaters in the facility.
4) Measurement of return loss.
5) Measurement of impedance.

This installer's set is completely self-contained, with its own signal source (oscillator) and detector (voltmeter), obviating the necessity of carrying several pieces of test gear. The installer's set requires only an external 48-volt supply, and can be used for testing and installing not only the AT-6 but also any existing AT-2 and AT-3 units. In testing the AT-6 (which is a combination repeater) it is possible to test either the series or the shunt section separately if desired. The installer's set can also be used to measure the return loss or impedance of the facility alone, if desired.

ROBERT P. DiMMER started with Automatic Electric in Quality Control in 1939 and was transferred to Laboratories a month later. He became a project engineer in 1947 and a senior project engineer in 1954. Now in the Product Design section of Automatic Electric Laboratories, Mr. Dimmer is actively engaged in the design and application of transistorized negative-impedance voice repeaters, and the design of control equipment for mobile radio-telephone systems. Mr. Dimmer was graduated from Northwestern University in 1950, with the degree of Ph.B. in Mathematics, and is a senior member of the Institute of Radio Engineers.



PORTABLE TELEPHONE EXCHANGE PROVIDES SERVICE TO NEW COMMUNITIE

By: R. W. Robb and G. S. Ballantyne
Automatic Electric Sales (Canada) Limited

Figure 1. Portable Telephone Exchange being moved to Location on Flat-bed Tractor-Trailer

Alberta Government Telephones, a provincial government agency (209,000 telephones), provides all public telephone service in the Province of Alberta, Canada, with two notable exceptions—the City of Edmonton Telephone System (111,000 telephones), municipally owned, and about 900 rural systems (30,000 telephones), which are farmer-owned mutual companies. The A.G.T., however, provides all long-distance service to the 350,000 telephones in the province. Since World War II, new discoveries of oil, natural gas and mineral resources have resulted in both a startling population growth and a rapid industrial development.

This has, of course, resulted in heavy demands for telephone service and has greatly accelerated the installation of unattended automatic exchanges (community dial offices or C.D.O.'s), both to replace outgrown magneto exchanges and to provide service in newly developed areas. In many of the latter cases, however, the location of temporary offices and housing for the construction forces might not coincide with that of the permanent townsite, so that the final exchange location would be difficult to determine in the early stages of development. An example of this situation was the construction of a large paper mill, utilizing natural gas as a fuel supply, at Hinton, Alberta, near two existing townsites, several miles apart. Telephone service was urgently required during the construction period, but the final growth pattern of the community was not immediately apparent.

These circumstances led to consideration of some form of portable exchange which could be used to provide initial service at a temporary site and which could be replaced later by a fixed installation. It was decided, therefore, to build a portable exchange for Hinton and to use the experience thus gained as a guide to future employment of such units.

Several organizations in Canada have been using mobile buildings to house similar equipment, and many of these were examined. A design used by one of the major oil companies and in certain defense installations was selected as being the most suitable for the A.G.T. This design incorporates a body of stressed steel sheets over a framework of steel channels, with interior lining and insulation, the whole mounted on heavy skids.

A portable building on skids was chosen instead of a mobile trailer on wheels because: (1) It would provide a more steady platform for the equipment; (2) It would be in service most of the time, and only infrequently in transit; (3) Low, flat-bed, tractor-trailers, such as used for the road transport of heavy machinery, were readily available throughout the province on a rental basis. A complete building, in transit, is shown in Figure 1.

DETAILS OF BUILDING

The two skids supporting the building are 10-inch "I" beams with curved ends and heavy tubular spacers, providing a rigid foundation. The double wood floor is supported by transverse 4-inch "I" beams, reinforced under the equipment bay locations. The body framework consists of specially shaped steel channel ribs with bolted joints (Figure 2). This framework is covered with sheet steel panels fitted to the vertical channel ribs and held by outer steel channels of smaller section; as these smaller channels are tightened into the main channels by bolts, they stretch the sheet steel panels, thus providing a stressed-skin structure of great strength and rigidity, which is sealed at the joints with weatherproofing compound. This patented construction, known as the "Lindsey" body, is widely used for truck and trailer bodies; the components, of American manufacture, are commercially available in Canada.

The body is lined with plywood on wood battens fastened to the steel channel ribs, and the space between the plywood and the outer sheet-steel skin is filled with glass fibre insulation, and provided with a vapor barrier. A 1½-inch square wood strip around the inside walls, 7 feet above the floor, provides a secure fastening for the auxiliary equipment framework. This strip is plainly seen in the interior view (Figure 3), which shows a completed building, ready for installation of exchange equipment.

A single door at one end is for normal use of maintenance personnel, and a double door at one side provides for the entry of equipment. Small windows, double glazed with Vibrin plastic sheet, are located high on each side, to provide good light without offering a means of unauthorized entry.

A propane gas-fired heater, with forced hot-air circulation, provides adequate heating for the prolonged Alberta winters—even with temperatures as low as —50°F. On the other hand, summer temperatures may rise to nearly 100°F., and for this reason, two electric ceiling-exhaust fans, with automatic shutters, are installed for ventilation. Semi-recessed lighting fixtures are mounted in the ceiling and walls, and power outlets provided as required. The heater-fan motor and controls, ceiling exhaust fans, lights, and power outlets are all wired to a 110/220 volt, 50-ampere service box, arranged for connection to an externally mounted watt-meter and commercial a.c. power supply.

Figure 4. Floor Plan Arrangement of Portable Telephone Exchange

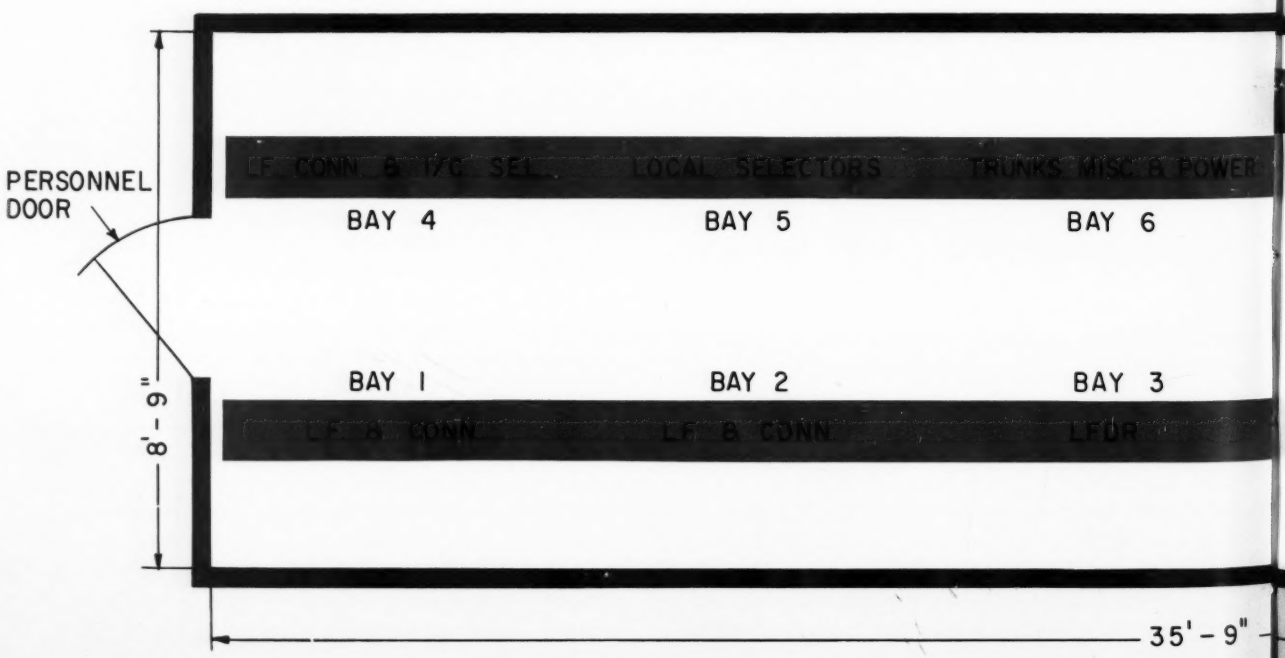
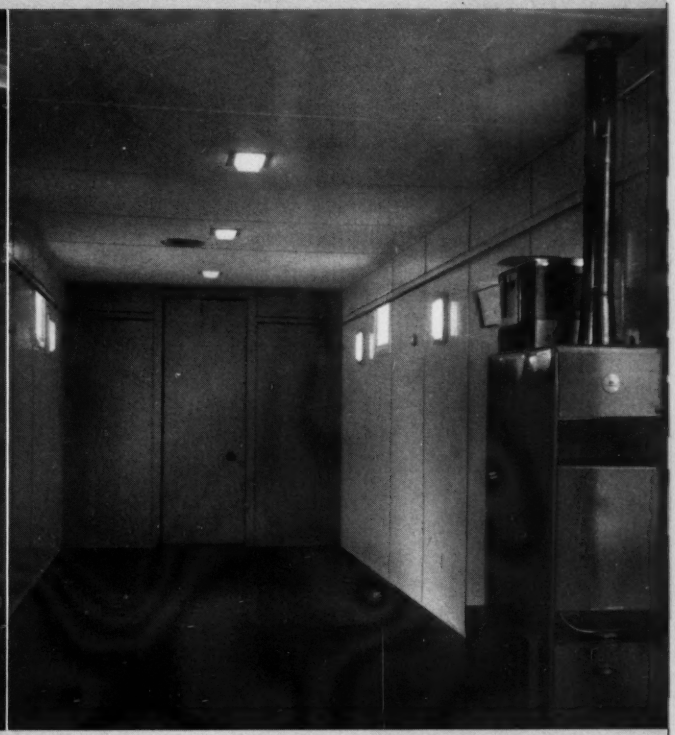


Figure 2. Body Framework Construction

Figure 3. Interior View ready for Equipment Installation



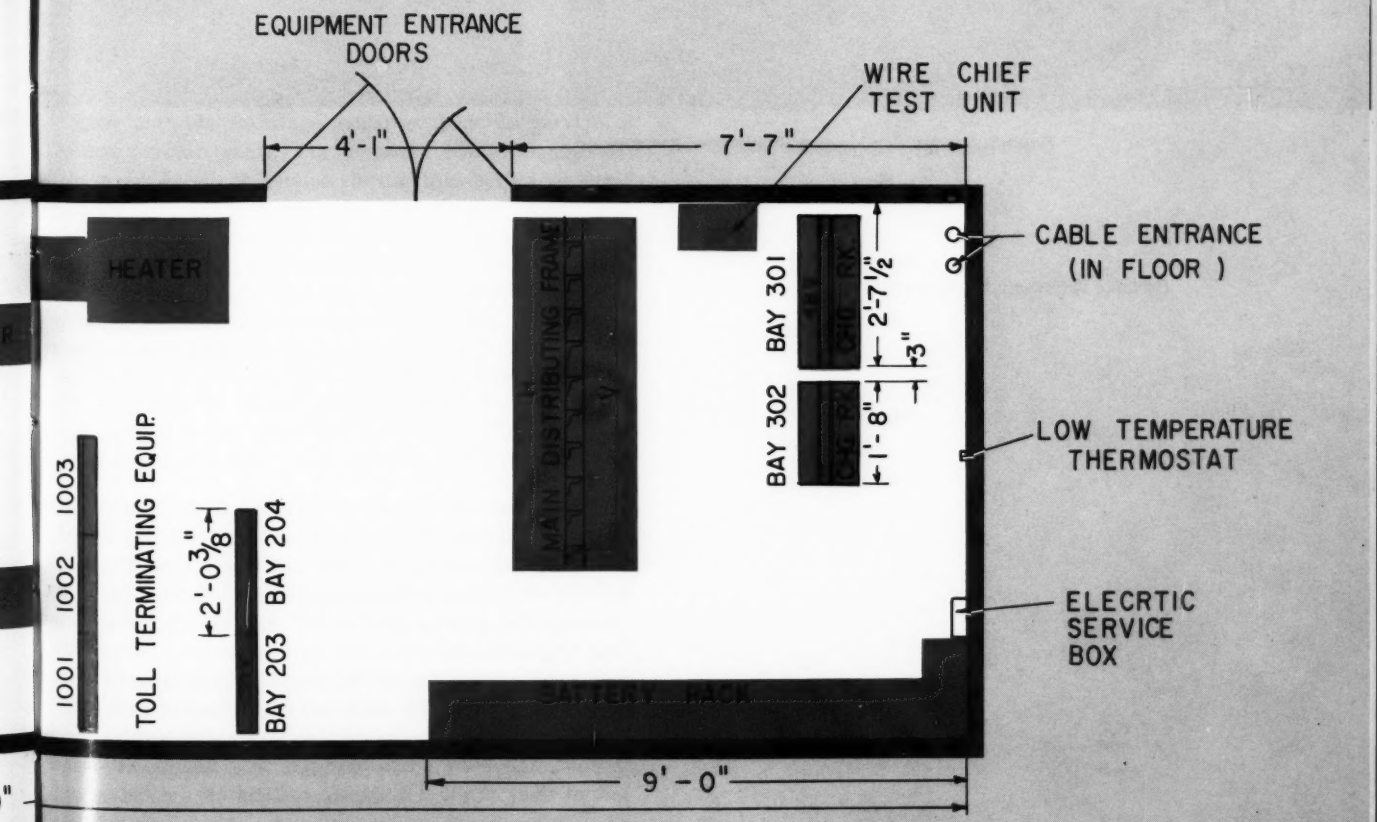


Figure 5. Interior View showing Switchroom Arrangement

Portable Telephone Exchange (Continued)

The portable building is 36 feet long, 9 feet wide, and 8 feet high. This provides adequate space for the switching equipment, plus the main distributing frame, power equipment and toll terminating equipment as required; the floor plan arrangement is shown in Figure 4. The building has a capacity of 500 lines, which is considered to be sufficient for most temporary exchange applications.

Standard stocklist units of Type 11 M-A-X equipment were installed in the portable building, at the A.G.T. shops in Edmonton, and the result was the attractive switchroom shown in Figure 5. The flexibility of the Type 11 units was proven by the fact that the only modification required consisted of minor changes in the auxiliary framework, to adapt it to the elongated shape of the portable building. All switches and other jack-in units of equipment were securely held by temporary wood battens, and the storage batteries were not mounted but left in their original shipping cartons on the floor.

TRANSPORTATION AND INSTALLATION AT SITE

The portable building, with equipment installed, was then transported some 200 miles to Hinton by road, using a rented flat-bed tractor-trailer as shown in Figure 1. At two points the building had to be dropped off the trailer and skidded under low overhead bridges; this maneuver was facilitated by use of the power winch on the tractor. Apart from this, no difficulty was encountered and no damage of note to the equipment occurred.

A temporary site adjacent to a highway had meanwhile been selected at Hinton, and the necessary outside cable plant installed. Aerial cable on wood poles was utilized, so subsequent re-routing to the eventual permanent exchange location would be at a minimum cost.

The temporary site was on a new toll route, to which 12 channels of medium-haul open wire carrier were added, 8 channels of which were used for two-way operator trunks to the controlling toll center at Edson, 55 miles distant. The carrier terminal equipment, with the necessary 130-volt power supply, was also installed.

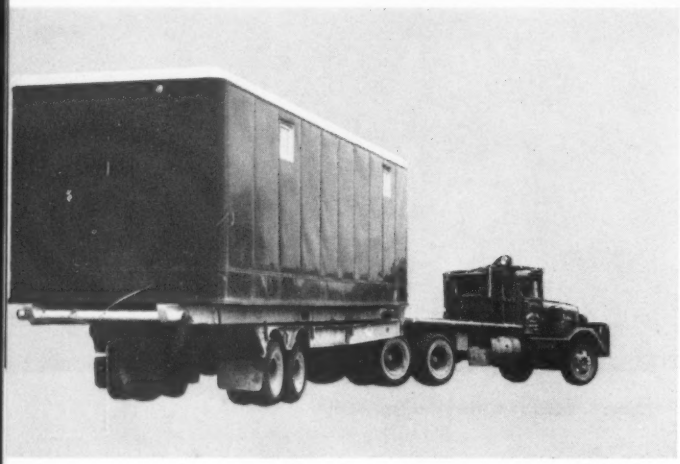
Upon arrival at Hinton, the portable building was unloaded at the temporary site and levelled, the storage batteries were installed (Figure 6), the equipment was checked, and connections were made to the local a.c. power supply, trunk lines and local cable plant.

EXPERIENCE GAINED AT HINTON

This portable exchange has now been in service at Hinton for two years. The Type 11 M-A-X equipment has given excellent service during this period of rapid growth — which included the installation of a large P-A-B-X with 8 trunks to the exchange. Additional units of Strowger equipment from the A.G.T. stores, quickly and easily installed, have been invaluable in meeting traffic demands.

The heavy traffic to the controlling toll center at Edson has indicated the need for greater capacity in the 48-volt power supply. It was also felt that a cable entrance through the end wall, with outside jointing, instead of floor entry with inside jointing, would be more convenient. These improvements were incorporated in the second portable building constructed, with successful results. This building was installed in a housing area on the perimeter of Calgary, and made it possible to provide service within 10 weeks from conception of the project. While the grade of service provided was naturally poor for a large urban dial area, and involved temporary numbering, nevertheless service was provided quickly, where otherwise nothing could have been done. In this connection it was found desirable to provide full digit-absorbing-type selectors for ultimate flexibility.

Figure 6. Storage Battery Arrangement



ECONOMIC ASPECTS

In view of the special nature and purpose of the portable exchange, it was not expected to compete in cost with fixed installations of the same capacity; nevertheless it appears to do so. The portable building is rated as a 20-year structure, as compared to the much shorter life of wheeled trailers, and is very competitive in cost to prefabricated steel buildings. The equipment costs are, of course, the same with the exception of a slight additional expense for modification of the auxiliary framework and battery rack.

There are, however, substantial savings in shipping and labor costs. Transportation of the complete building and equipment at $0.95 per mile was found to be equal to freight charges for the equipment alone over the same distance, thus saving the cost of freight on a comparable prefabricated building.

Assuming four men spending four weeks installing the equipment in the portable building at the shops in their home area, and only one week in placing the exchange in service at the operating site (instead of 5 weeks at the latter, which would be required in the case of a non-portable installation), there is a saving of about $5.00 per man per day, or over $500 for out-of-town living expenses, plus some intermediate travelling expenses.

ACCEPTABILITY

The introduction of any radical change in established practice is bound to cause some reactions from the personnel involved. The attitudes of staff and subscribers to the portable exchanges were carefully observed and were found to be favorable in all cases. The installers were very pleased that most of their work was performed in their home area, with all shop facilities at hand, as compared with the makeshift and expensive accommodations of a new town. The maintenance personnel found the portable buildings comfortable to work in and the equipment easy to maintain. Subscribers, impatient for service, and accustomed to the usual slow erection of a building and installation of equipment, were surprised and pleased with the speedy introduction of service made possible by the portable exchanges.

CONCLUSION

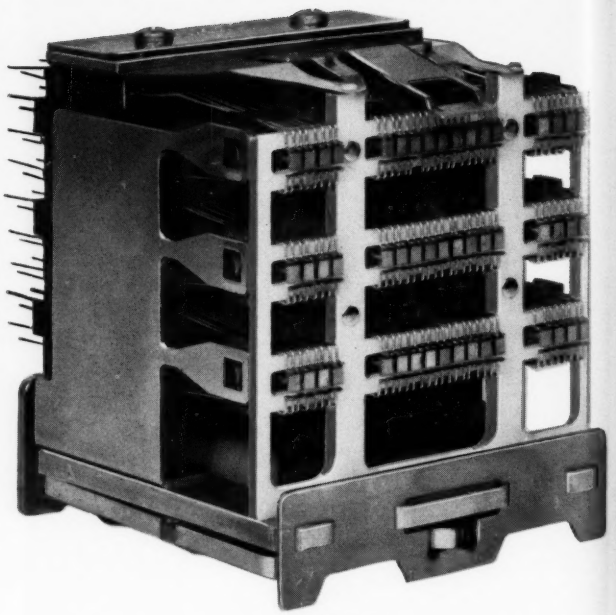
The value of these portable exchanges in providing telephone service quickly to new communities seems conclusive. With the addition of a portable, engine-driven, a.c. power supply, they would be invaluable in case of any disaster which interrupted regular telephone service. No abnormal costs are involved in their construction or maintenance, and the reaction of staff and subscribers is most favorable.

ROBERT W. ROBB joined the staff of Canadian (B.C.) Telephones & Supplies Limited, the Automatic Electric installation organization in Canada, in 1942, and for the following ten years was engaged in the installation of automatic telephone equipment throughout western Canada. In 1952 he was transferred to Automatic Electric (Sales) Canada Limited as a staff assistant in Telephone Sales at their head office in Toronto. He was appointed in 1954 to his present position of Western District Manager, at Edmonton, Alberta.

GORDON S. BALLANTYNE graduated in 1950 from the University of Manitoba with a B.S. degree in Electrical Engineering. He began his communications career in the Engineering Department of the Manitoba Telephone System. In 1954 he joined the staff of Automatic Electric Sales (Canada) Limited as Sales Engineer on telephone equipment at Edmonton, Alberta. He is now specializing on carrier and radio equipment sales engineering.

THE CLASS "W" WIRE-SPRING RELAY

By: G. A. Borling and G. S. Lychyk



Class "W" Relay, shown without cover.

The Class "W" relay was designed to meet the need for an industrial switching component that would switch a multiplicity of contacts at moderate voltages and currents, and with minimum power consumption. A maximum of 50 sets of transfer contacts were required.

Telephone-type relays do not lend themselves to spring pileups of this size, and the use of multiple-connected relay groups to switch large numbers of contacts has the disadvantage that variations in operating speeds between individual relays would make it difficult, if not impossible, to insure break-before-make operation, essential in certain circuit applications. In order that relays be capable of long life and a high degree of reliability, yet be economical to manufacture, their design must utilize the most advanced methods of fabrication, assembly, and adjustment.

The following design requirements were established for this new relay:

Contacts

A maximum of 50 form C (break-make or transfer) contacts capable of carrying a load of 3 amperes at 50 volts, non-inductive load, with a maximum contact resistance of .100 ohms.

Power

The maximum input power must not exceed the equivalent of 0.300 amperes at 30 volts, or 9 watts. This is based on the requirements for a nominal 24-volt relay, 30 being the maximum expected input voltage. For the same 24-volt nominal requirement the relay must operate reliably on 18 volts.

Dielectric Strength

A minimum of 1500 volts, a.c., rms, is required between open contacts, between adjacent springs, and from springs to frame.

Insulation Resistance

A minimum of 1500 megohms (1.5×10^9 ohms) at 80°F, 88% R.H. This requirement must be met between any individual spring and all other springs electrically commoned, and between any spring and the frame. This requirement was necessitated by the fact that application requirements could specify that all but one spring be at a common circuit potential.

Life Expectancy

To conform to existing standards of performance the relay must be designed for long life with a minimum of maintenance and adjustment.

Adjustment

For economy, the design must permit rapid assembly and minimum adjustment during manufacture and during the normal life of the relay.

Wiring

Because of the number of connections required for each relay, solderless wrap terminations were specified for both the spring and coil connections, each terminal to accommodate two connections of either 24 or 26 gauge wire.

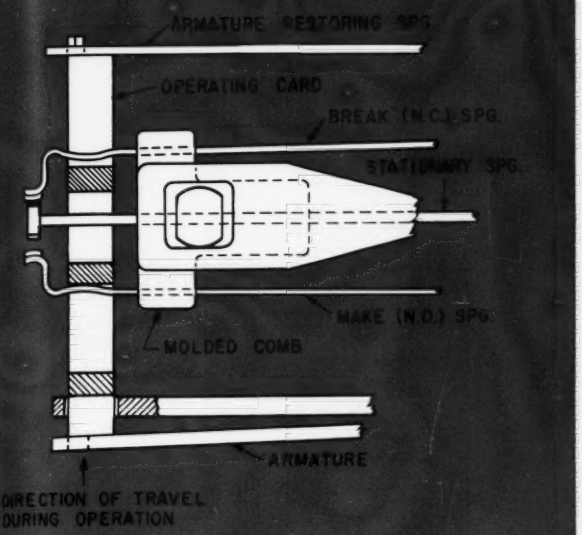


Figure 1. The "Operating Card" Principle

Design of Spring Assemblies

After considering a number of conventional telephone relay constructions, a wire-spring design was selected as the most suitable. It was determined that, by using the "operating card" principle (Figure 1), the frictional load at the wear points could be reduced to that of individual wire tension, with each wire spring resting individually against a separate point on the operating card. The only portion of the card supporting the load of a number of springs is that portion which contacts the relay armature, and here the load is applied over a substantially large area. Also, at these points the sliding between the contacting members is appreciably less than it would be on more conventional type mechanisms.

Twin wires are used for the movable springs, resulting in almost completely independent action for maximum contact reliability. The center contact is located on a rigid stationary wire and the contact pressure is derived by tensioning the smaller movable wires against the stationary contact assembly. These movable wires, which have precious metal contacts attached at the free end, are operated upon by the operating card, thus assuring positive movement of the movable springs and minimizing the possibility of contacts welding.

Another reason for selecting this method of operation, as compared to the buffer-type actuation, is the compensating effect of card wear at the point of contact with the individual springs. Wear on the card results in a decrease in the open-gap contact spacing, which compensates for mechanical and electrical erosion of the contacts.

To insure correct contact-alignment, a molded comb is provided immediately beneath the contacts on the stationary spring assembly. The smaller movable spring wires are guided by this comb, with extensions on either end of the comb serving as a means of locating and positioning the stationary contact group.

A.E. Code 0 (50% Palladium, 50% Silver) contacts are used to meet the current and contact-resistance requirements. Contacts are secured to the stationary wires by a nickel-silver backing with a 10 mil overlay of the precious metal material. The contacts on the movable wires are of similar construction and are resistance-welded to the nickel-silver wires. To insure proper mating of the contact pairs, the contacts on the movable wires are "coined" to a curved configuration after welding.

Since a relay of this type could prove economical, from both a size and cost standpoint, with fewer than 50 contact sets, we arranged the contact groups in separate levels which could be assembled in combinations of one, two, or three levels. By molding each level of 17 springs (or pairs of springs, in the case of the movable wires) into an integral unit, combinations of 17, 34, or 51 contacts can be furnished. The largest possible combination that can be provided is 51 form C contacts; however, forms A (make) or B (break), or combinations of forms A, B, and C can also be provided. A thermosetting molding compound is used; suitable interlocking bosses are provided to key the asembly together and assure proper alignment. The location bosses at the extremities of the molded comb on the stationary wire assembly are anchored into adjustable arms on a metal frame, and these arms serve as a means of positioning the stationary contacts during relay adjustment. Because of the accuracy with which the contacts can be located during manufacture, group adjustment of these contacts is the only positioning required. The stroke is fixed by the design of the armature assembly, and margining requirements are met by removal of tension from the single armature-restoring spring located at the outside of the spring pileup, Figure 1.

In considering the electrical requirements for these contacts, particularly in industrial applications, it was necessary to provide one-quarter-inch creepage paths at the terminal ends of the wires where the cover does not provide protection. This was done by providing steps in the molded portion of the spring assemblies as illustrated in Figure 2. Where solder connections are used, the danger of surface contamination of the insulation by the solder flux is thus also alleviated.

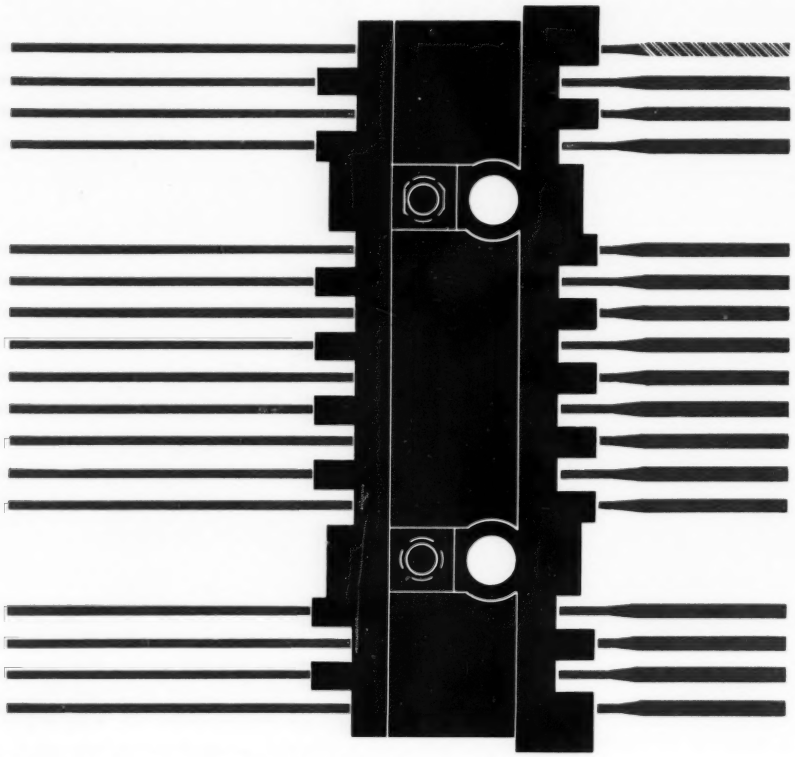


Figure 2. "Step" Design of Insulation provides one-quarter inch "Creepage" Distance

Magnetic Circuit

Because of the need to operate the large spring load of the Class "W" relay at a reasonable power level, research was carried on to determine the most suitable magnetic configuration. In considering the equation for the attractive force of an electromagnet:

$$F = \frac{(NI)^2}{AR^2}$$

where F = attractive force
NI = ampere turns
A = effective pole-face area
R = reluctance

it can be seen that the force is a function of the second power of the reluctance. The reluctance of the air gap is an appreciable portion of the total reluctance of the circuit; the importance of this can be seen in Figure 3, which illustrates a typical load curve of the relay, and pull curves of the armature assembly. The crucial point on the load curve occurs at a point in the stroke at which there is still an appreciable air gap. Design efforts were directed at securing the maximum attractive force at this point.

An Instron testing machine was used to plot a pressure-deflection curve for evaluating the pull characteristics of each structure tested. The machine consists of a strain-gage amplifier and a means for synchronizing the rate of deflection of the mechanism under test with the feed of a chart drive. By this means a "family" of pull curves can be obtained in a matter of minutes, compared to hours and even days required by the previously used techniques.

The structure chosen is an "E"-core design (see Figure 4), and has a low open-gap reluctance, which is essential for this application. In place of the armature bearing pin used on many relays, the armature is supported on a flat nickel-silver spring. At the pivoting end of the armature, between the armature and the magnetic core, a nickel-silver wear plate is provided, which also serves as a residual disc.

The stroke of the magnetic circuit is fixed at .050". The free end of the armature assembly is restrained by a non-magnetic member fastened to the open end of the core assembly. In the de-energized position this member functions as a backstop for the armature. The stroke, built into the operating card, is determined by the length of the extension of the card through the core.

LOAD OR PULL IN GRAMS

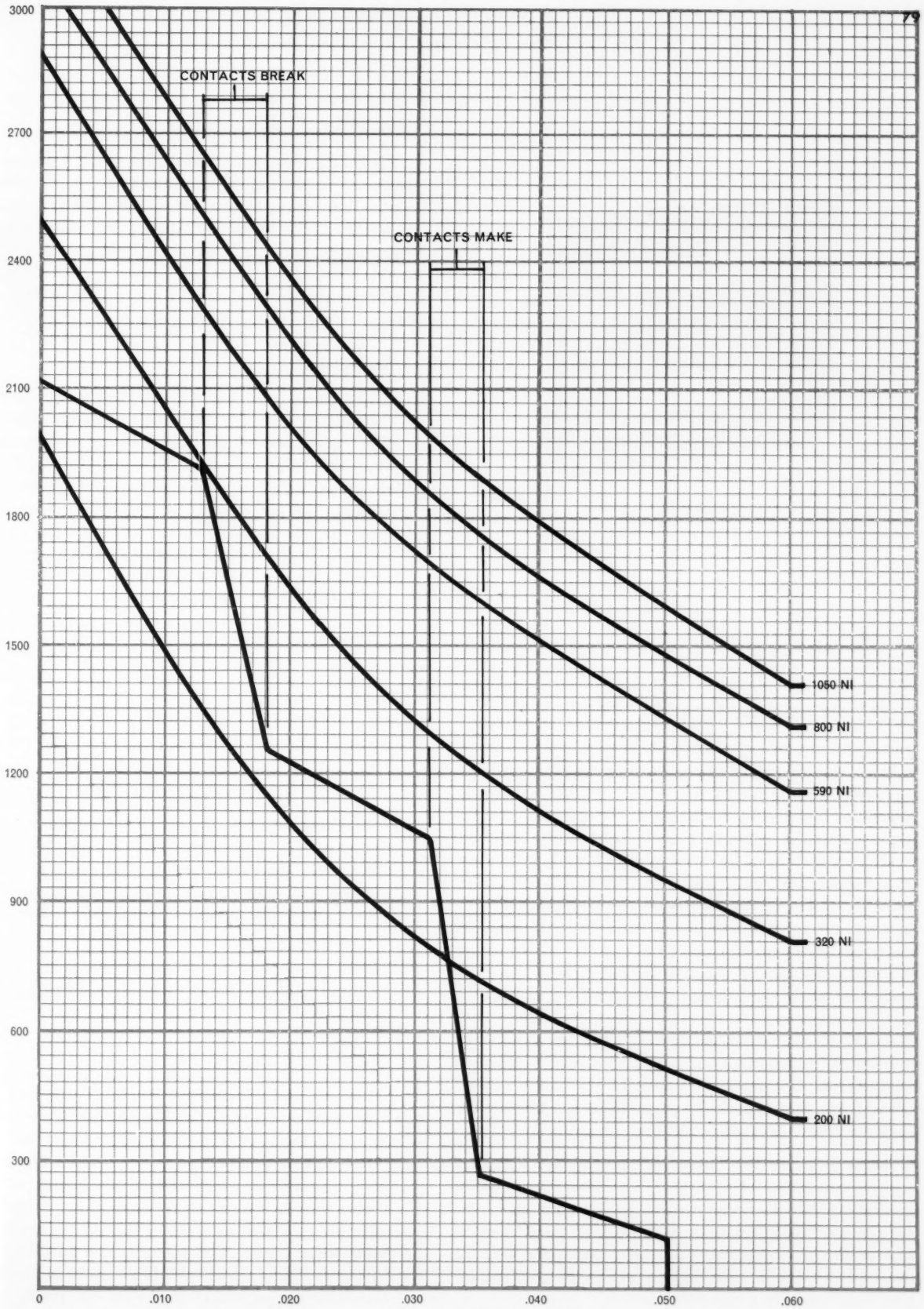


Figure 3. Typical Load and Pull Curves

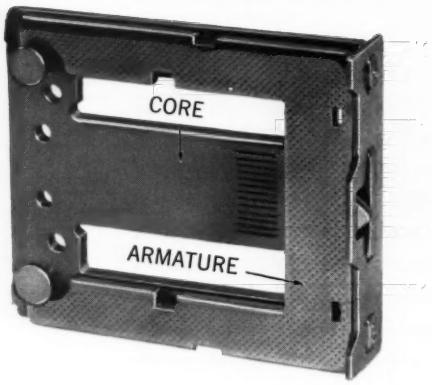


Figure 4. "E"-Core and Armature

SELECTION OF MATERIALS

Many of the materials used in this relay were chosen to meet specific requirements peculiar to non-telephone applications of switching relays. For the molded spring assemblies and the operating card, for example, general purpose phenolic would be a good choice under ordinary conditions, because of its moldability, strength, good electrical properties, and reasonable cost. Under severe humidity and moisture conditions, however, coupled with demands for increasingly higher insulation resistance, it was necessary to specify a material less susceptible to the effects of moisture. A lengthy series of tests was conducted on all known materials suitable for this application, encompassing the effects of time, temperature, and humidity on the electrical characteristics. As a result of these tests, and further consideration of the mechanical requirements for the material, a diallyl-phthalate molding (DAP) compound, partially glass-filled, was selected for both the spring insulation and the operating card.

Figure 5 shows the results of an extended humidity test on specimens of both the "DAP" material and a general-purpose phenolic material. The insulation resistance of the "DAP" material may be more than 10 times that of the general-purpose phenolic, under the severest use, and the rate of both decline and recovery of insulation resistance are markedly superior.

OPERATING CHARACTERISTICS

There is no one characteristic by which a relay can be measured to determine its suitability for all switching applications; *all* of the characteristics must be considered, in terms of the particular application. Since complete performance data on production units is not available at this time, typical data taken from evaluation tests on prototype samples are given; some variations from these figures may be expected on production units:

Sensitivity

Increasing importance is attached to the power requirements for electromagnetic switching components. The "just operate" power sensitivity, defined as the minimum value of power, in watts, which will cause the relay to operate, is one measure of the overall efficiency of the design, as it incorporates both the magnetic efficiency of the structure and the electrical efficiency of the coil. For purposes of comparison, both ampere-turns and power sensitivity are given for several typical A.E. relays:

"Just Operate" Sensitivity

Relay	*Milliwatts/ Form C*	*Ampere-turns/ Form C*
Class B (Note 1)	29	34
Class E (Note 1)	104	47
WQA (Note 2)	18	6.2

Note 1—Data based on a standard 8C spring load
Note 2—Data based on a standard 51C spring load

It is interesting to note that the ampere-turn sensitivities of the Class B and Class E relays are comparable, while the power sensitivities are not. One important factor here is the appreciably greater coil volume available on the B relay, which results in a lower resistance per turn (or ampere-turn).

The 24-volt coil (110 ohms) draws 5.2 watts at nominal voltage and the "just operate" voltage is approximately 10 volts (corresponding to 0.91 watts).

Operate and Release Characteristics

Operate and release time values, measured on prototype samples using the 24-volt, 110-ohm coil, are shown in Figure 6. The armature restoring spring is a factor in determining the proper balance between operate and release time, and in production units the timing will be controlled by adjusting this tension to effect an equitable balance for the various spring combinations available. Coil power is also a factor, as seen in Figure 6, and the operate time can be improved substantially by increasing the input coil power.

MEGOHMS

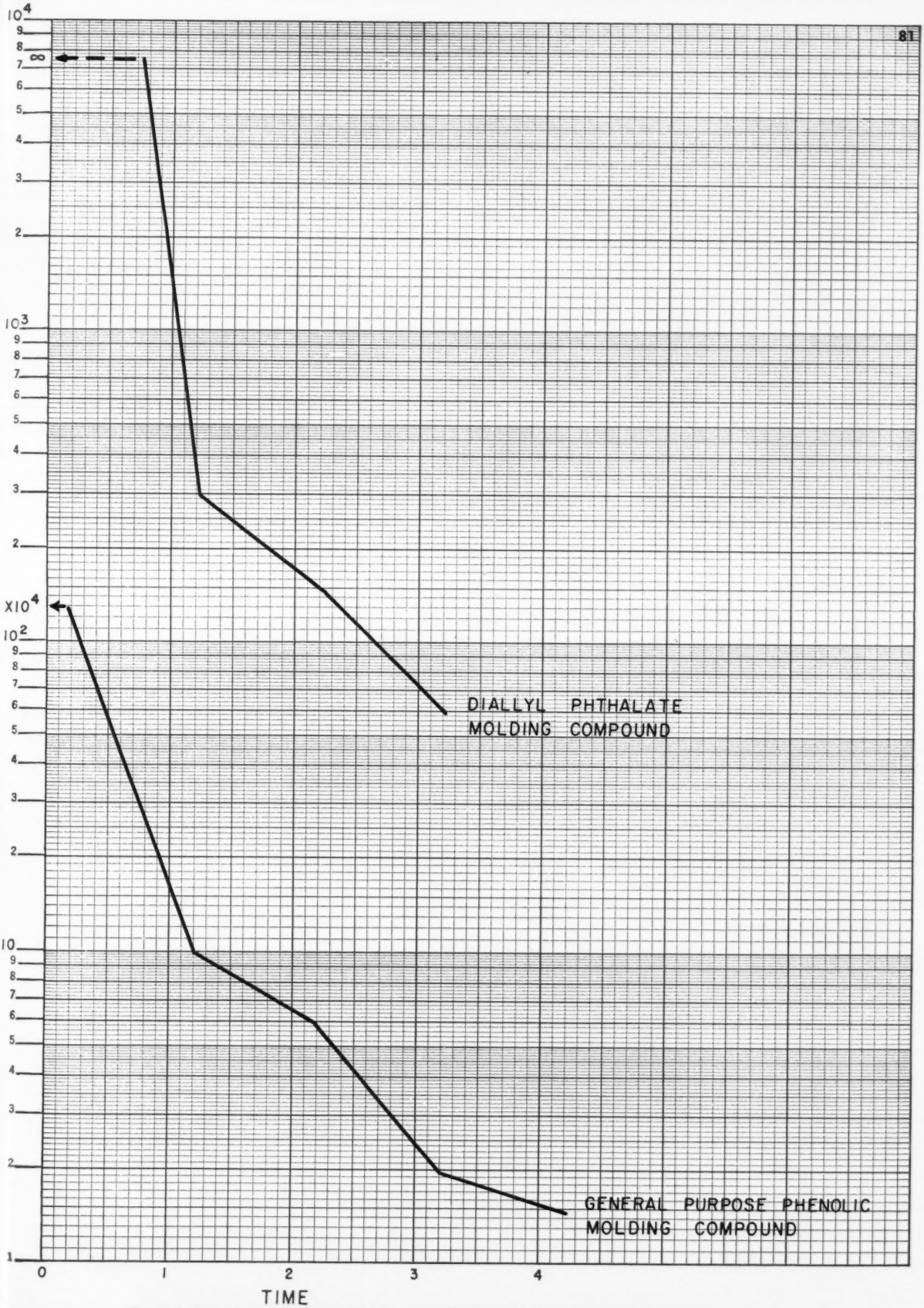


Figure 5. Comparative Insulation-Resistance of "DAP" and "General-purpose" Insulations

Load and Pull Curves

Figure 3 shows typical load and pull characteristics for an assembly of 51 form C contacts, at various ampere-turn levels. (In operating the structure to obtain these curves the movement was slow enough to insure that dynamic conditions were not a factor.)

It can be seen that the load increases sharply at two points. Reading the load curve from right to left (in the direction of relay operation) the first point is as the operating card picks up the load of the normally closed (break) springs. The second-step increase in the slope of the load curve occurs as the normally open (make) contacts close and the tension of the associated springs is transferred from the operating card to the contacts. This shows up as an increase in load, for the reason that the tension of the make springs on the operating card was in a direction to aid the operation of the relay.

The minimum value of ampere-turns that will fully operate the relay is approximately 320. If a non-operate margin requirement is to be specified it can be seen that this value must be 200 ampere turns or less. An intermediate value of ampere turns will result in partial operation of the relay, with the armature travel stopping at the point in the stroke at which the pull developed by the coil is equaled by the magnitude of the load.

Contact Loading and Life Expectancy

The contacts are rated to carry 3 amperes, 150 watts, non-inductive load. Life comparable to that of a telephone-type relay is expected. One factor which contributes to the life of the contacts, particularly under conditions of arcing, is the extremely short duration of the contact chatter, or bounce; here, the low mass of the movable springs is a major factor. During release of the relay the rebound energy of the armature

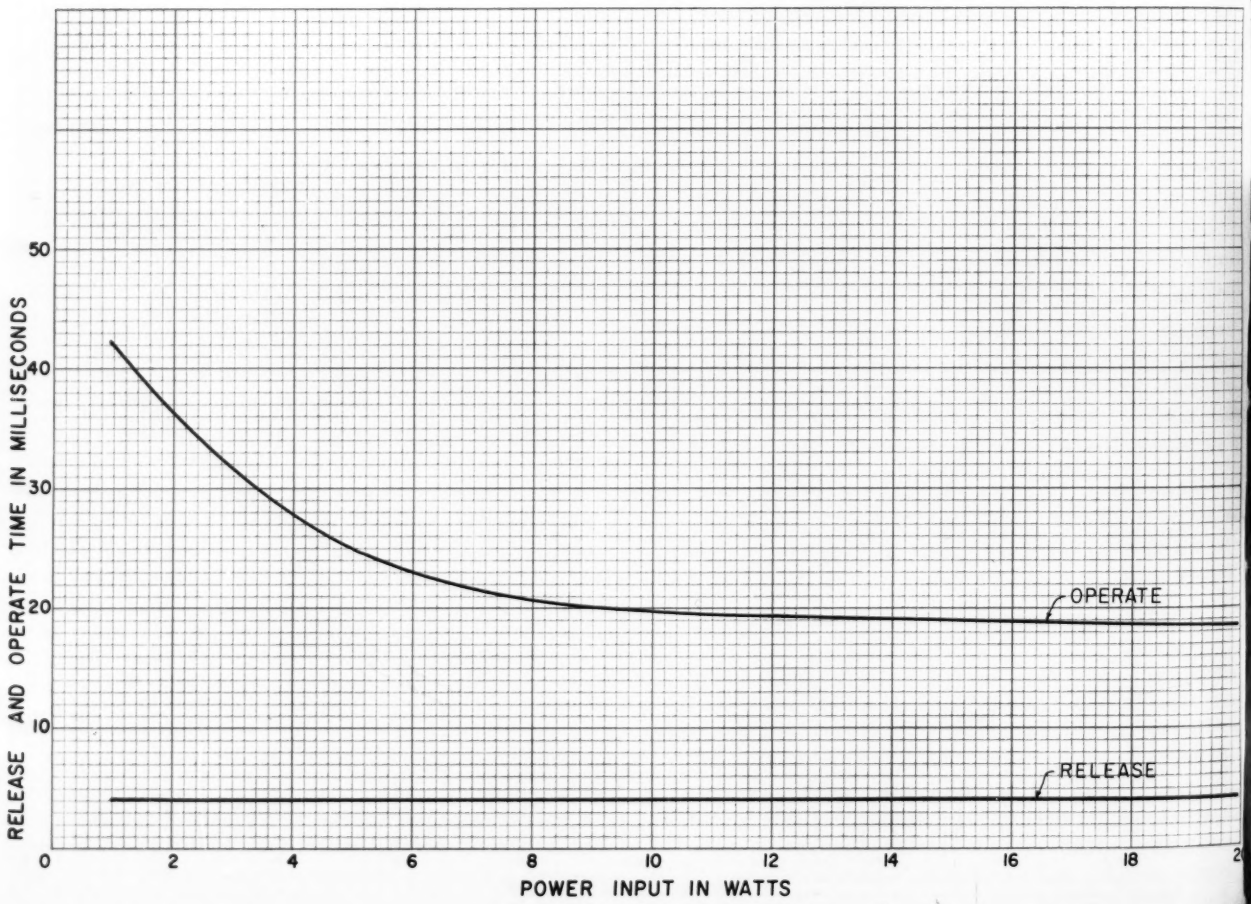


Figure 6. Operate and Release Characteristics of Typical Assemblies

is absorbed by the armature-retaining spring, which helps to reduce the chatter of the normally closed (break) springs.

Initial tests on prototype samples are still in progress, and indicate that the adjustment-free life of the relay will be in excess of 70 million operations. Figures on the life expectancy of loaded contacts are not available at this time, and are difficult to predict because the life is dependent to a large degree on the type of loading and the environmental conditions.

MOUNTING

The Class "W" relay mounts with four No. 8-32 screws. The recommended mounting position is with the armature and the operating card in vertical planes; this minimizes the effect of the weight of the armature.

The development of this long-life, high reliability relay, capable of switching large numbers of circuits, at an economical operating power level, is another step in a program to provide advanced telephone and industrial switching components.

GEORGE S. LYCHYK joined Automatic Electric Laboratories in 1956. After several years in the Power and Signaling Section, he was transferred to the Electro-Mechanical Design Section, where he is engaged in the development of electro-mechanical components. Mr. Lychyk received his B.S. degree in Mechanical Engineering from the Chicago Technical College. He is a member of the American Society for Metals.

GLENN A. BORLING received his B.S. in E.E. from Illinois Institute of Technology. He became associated with Automatic Electric as a student engineer in 1948, and in 1950 was transferred to the Laboratories as a project engineer. He is now serving as a group leader in the Electromechanical Design Section where he is active in the development of telephones and relays. Glenn is a member of A.I.E.E. and American Society for Metals.

THE TYPE 59 "CODEL" RELAY

ELIMINATES FIELD ADJUSTMENT

By: Irwin A. Cohen

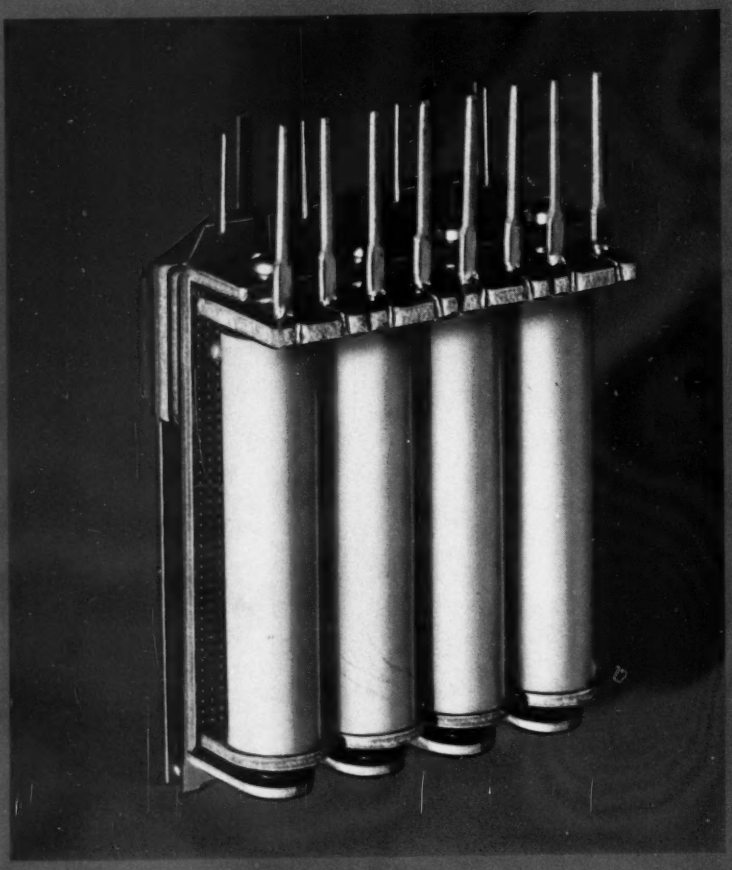


Figure 1. The "Codel" Relay

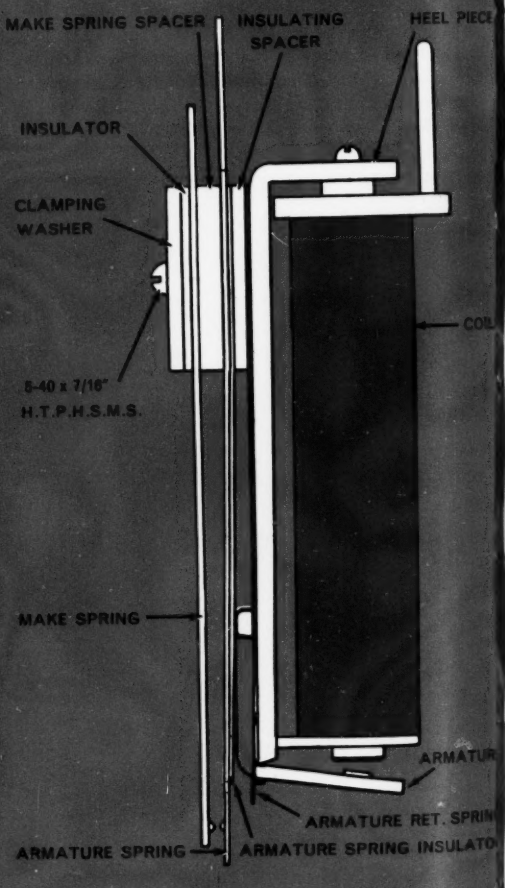
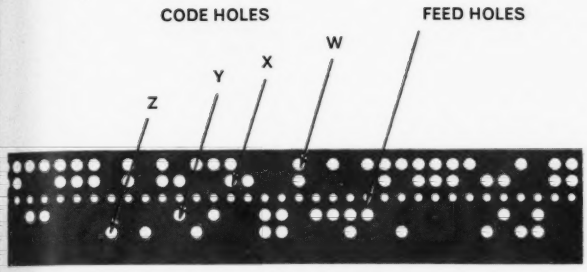


Figure 2. Schematic Line Drawing of "Codel" Relay



Billing Tape showing "Codel" Four-element Coding System

The final product of a SATT system is a strip of perforated paper tape (as shown above) containing all the information necessary for billing the subscriber for toll services rendered. This information is in "Codel" code, a four-element coding system used for translating, storing, and sending digital information from one piece of SATT equipment to another. Codel relays play a substantial part in the translating, storing, and sending of this information.

All data received from the Ticketer must be stored on sets of Codel relays in the Tabulator in order to permit insertion of data normally connected to the Tabulator directly, and to clear the Ticketer as rapidly as possible. The sending speed of the Tabulator is controlled by the maximum speed of the tape punch which is slower than the speed with which information can be spilled and stored from Ticketer to Tabulator. Information from the Ticketer is forwarded to four wipers of a twenty-five point rotary switch which extend it to the Codel relays; it is then forwarded to the tape punches by four wipers of a fifty point rotary switch which scan the Codel relays, the strapped information in the Tabulator, and the Dater-Timer terminals.

The first Codel relays to be used in a SATT system were Type 58 mounted individually on a base; they are still being used for certain applications where more than one make combination per pileup is required. The next Codel relay used in the system was the so-called Codel "cluster" consisting of four individual YQA type relays mounted on a common bracket, wired as a unit. Since this arrangement is used many times in the system, we believed that economies in manufacture could be achieved by designing a special unit to replace this "cluster".

Our basic goal was to design a relay that was economical to manufacture; also we wanted to completely eliminate the need for manual adjustment. The customer could achieve substantial labor savings by eliminating the periodic readjustment required by the Type 58 relay and the YQA.

The first Type 59 Codel relay (Figure 1) was available in 1959; the designation "Type 59" was used since the relay was to be used predominantly in the SATT system of the same name. The relay uses four coils on a common heelpiece (Figure 2) because it would be most flexible in application to the existing system. The possibility of magnetic interaction between coils on the common heelpiece was investigated with results showing variations of one or two milliseconds in operate and release times, which was not considered significant in light of the application of these units. We used a common make spring because of the circuitry involved, and twin contact springs to increase the reliability of closures. We eliminated all manual adjustment by designing the margining and gauging into the fabricating process. The armature springs are fabricated as one unit with tie strips holding them together at each end. The springs are pretensioned in a forming tool; the amount of form produces the correct pressure against the armature in the non-

operated condition of the relay. The correct contact pressure upon operating the relay is achieved by having the proper space between armature spring contacts and make spring contacts, and by having the proper form angle in the armature. After the relay is assembled, the tie strips are clipped off and the unit is ready for inspection.

The welding of contacts on both fixed and moving springs is accomplished by means of a semi-automated process. After an initial set-up has been made and the first contact welded, the remaining seven welds on each spring group are accomplished automatically by an ingenious indexing device, which aids in producing uniform heading of each contact and perfect contact alignment. Additional manufacturing savings accrue by eliminating the set-up time for eighty-seven percent of the welds.

Wire-wrap terminals are used to eliminate the need for tinning and soldering, and to benefit by obtaining a gas-tight, corrosion-resistant connection which is less subject to breakage due to vibration, and permits easier inspection and tracing of defective joints. Terminals are long enough to accommodate two wrapped connections.

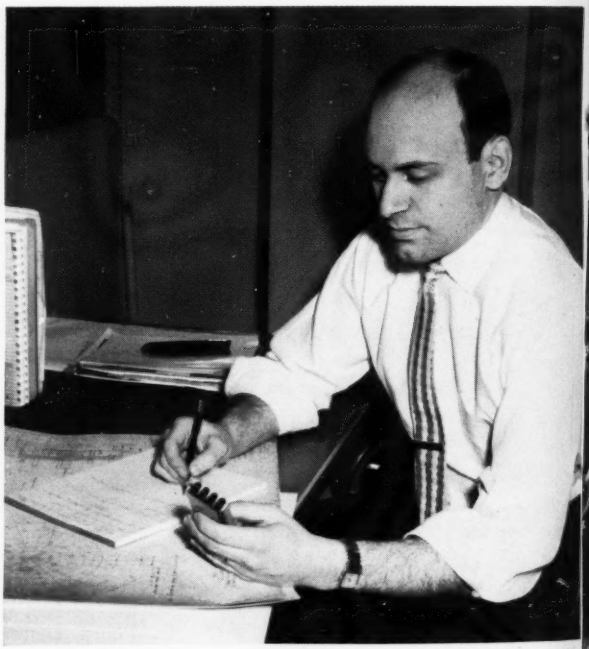
Since the adjustment of the Type 59 Codel relay has been designed into its construction, its operating characteristics are fairly broad in comparison with a manually adjusted relay. This is because the manufacturing processes involved do not allow for as close tolerance control in margining and gauging as would be in the case of a manually adjusted relay. However, the unit will normally operate very satisfactorily in the SATT system.

There are other applications for Codel relays in toll practice. In the Type 31-C and FW-1 toll systems, for example, Codel relays are used for digit storage in impulse sending circuits. These units will also be modified to use the Type 59 Codel relay.

MAINTENANCE

Each armature may be removed and reformed to change the stroke, which in turn will change the contact pressure and release current value; a faulty coil may also be easily replaced. The make spring is quite rigid and not likely to be damaged, and since the armature springs are well protected by the make springs, in normal handling they should not be disturbed.

Life testing of the Type 59 Codel relays showed no failure; this life test simulated twenty-five years of field service.



IRWIN A. COHEN, staff engineer, Automatic Electric Laboratories, joined Automatic Electric in 1954 as a student in the Engineering Training School. Later assigned to the Product Design Department of Laboratories, he is now doing design and development work on electromechanical components. Mr. Cohen received his B.S. in Mechanical Engineering from the Illinois Institute of Technology, and is currently engaged in graduate studies leading to an M.B.A. degree at the University of Chicago. He is a member of the American Society of Mechanical Engineers and the Western Society of Engineers.